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MARKET DISEASES OF FRUITS AND VEGETABLES: TOMATOES, PEPPERS EGGPLANTS

By

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TOMATOES, PEPPERS, EGGPLANTS [1]

By Glen B. Ramsey, *Senior Pathologist, Division of Horticultural Crops and Diseases, Bureau of Plant Industry, United States Department of Agriculture*, and George K. K. Link, *Professor of Plant Pathology, University of Chicago, and Collaborator, Bureau of Plant Industry*

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[1] This publication is the second in a series designed to aid in the recognition and identification of pathological conditions of economic importance affecting fruits and vegetables in the channels of marketing, with a view to facilitating the market inspection of those food products and reducing and preventing losses from such conditions. The series represents an extended revision and elaboration, with the addition of illustrations, of a preliminary publication entitled "Handbook of the Diseases of Vegetables Occurring Under Market, Storage, and Transit Conditions," by George K. K. Link and Max W. Gardner, which was published by the Department of Agriculture in 1919 especially for the use of the food-products inspectors of the Bureau of Agricultural Economics and was never distributed to the public. In addition to his part in the authorship of the preliminary edition, Doctor Gardner participated in a portion of the revision embodied in the present publication. The material is organized on the basis of the botanical families to which the plants belong, but no botanical system is followed in arranging these families. Practical conditions make it desirable to issue the material in separate sections arranged somewhat in the order of the economic importance of the crops. The Host Index of the Fungi of North America, by A. B. Seymour, 1929, is used in the main as a guide to the nomenclature of causal fungi, and to the names of authorities therefor. The colored plates, except as noted below, are reproduced from colored photographs prepared through the collaboration of Webster Bros., Chicago, Ill., under the direction of George K. K. Link, Max W. Gardner, and Glen B. Ramsey. The originals of Plates 1, C; 2, C; 3, E; 4, A; 5, C; 6, A; 7, C; 9, E; and 10, D, were photographed and colored by Glen B. Ramsey. D and E of Plate 2 are from photographs furnished by Mary K. Bryan and colored by Webster Bros.

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TOMATOES

INTRODUCTION

The tomato of the market is the fruit of the tomato plant (*Lycopersicon esculentum* Mill.), a member of the Solanaceae or nightshade family. To be desirable for salad purposes tomato fruits must have good shape, clear red color, good flavor, and firmness, and must be free from mechanical injuries, blemishes, and decay. They must be ripe, without being soft and flabby.

The all-year-round demand for tomatoes for salad purposes necessitates the shipment of these tender fruits over long distances. Since the ripe fruit is exceedingly subject to bruising and decay, the southern crop is harvested before it reaches full ripeness. The fruits are picked in a mature green condition, so that they may either ripen in transit or complete the process upon arrival in the markets. Ripening in the markets generally is forced by placing the fruit in ripening rooms with a temperature of about 70° F. and a high humidity. Under such conditions tomatoes picked at the proper stage of maturity ripen within a few days, whereas immature ones ripen slowly, and often are so blemished or affected by decay before they ripen that they are unfit for marketing. The high temperature and humidity of the ripening rooms are extremely favorable for the development of tomato fungi, some of which are carried from the field on the surfaces of the fruit and some abound in the ripening rooms.

The tomato plant is subject to a great many of the diseases that attack other members of the nightshade family. In addition the fruit especially is subject to a considerable number of specific maladies.

There are many field diseases that attack the vines, thus reducing the yield and often indirectly affecting the quality of the fruit. Among these are: Ascochyta blight (*Didymella lycopersici* (Brun.) Kleb.), crown gall (*Bacterium tumefaciens* Smith and Town.),[2] damping off, *Pythium debaryanum* Hesse; see Potato [3] p. 33), edema, Fusarium wilt (*Fusarium lycopersici* Sacc.), gray leaf spot (*Stemphylium solani* Weber), leaf roll, root knot (*Caconema radicicola* (Greef) Cobb), Sclerotinia rot (*Sclerotinia sclerotiorum* (Lib.) Massee), southern bacterial wilt (*Bacterium solanacearum* (E. F. Smith) E. F. Smith;[4] see Potato, p. 14), Verticillium wilt (*Verticillium alboatrum* Reinke and Berth.; see Potato, p. 50), yellows, and insect injuries of various kinds induced by aphids or plant lice (many species of the Homoptera, family Aphididae), beet leaf hopper (*Eutettix tenellus* Baker), blister beetle (*Epicauta vittata* Fab.), flea beetle (*Epitrix parvula* Fab. and *E. cucumeris* Harris), and white fly (*Trialeurodes vaporariorum* Westw.).

There is even a longer list of diseases that affect both the vines and the fruit. Among these are some of the most important tomato diseases, some of which attack the fruit not only in the field but in transit as well. Diseases of this type are: Alternaria rot (*Alter-*

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[2] Syn., *Phytomonas tumefaciens* (Smith and Town.) Bergey et al.

[3] References in this publication to Potato, followed by page numbers, relate to the following publication:

LINK, G. K. K., and RAMSEY, G. B. MARKET DISEASES OF FRUITS AND VEGETABLES: POTATOES. U. S. Dept. Agr. Misc. Pub. 98, 62 p., illus. 1932.

[4] Syn., *Phytomonas solanaceara* (E. F. Smith) Bergey et al.

naria solani (Ell. and Martin) Jones and Grout, and *Alternaria* spp.), anthracnose (*Colletotrichum phomoides* (Sacc.) Chester), bacterial canker (*Aplanobacter michiganense* (E. F. Smith) E. F. Smith[5]), bacterial spot (*Bacterium vesicatorium* Doidge[6]), gray-mold rot (*Botrytis* sp.), green-mold rot or leaf mold (*Cladosporium fulvum* Cke.), late blight (*Phytophthora infestans* (Mont.) DBy.), mosaic, Phoma rot (*Phoma destructiva* Plowr.), Sclerotium rot or southern blight (*Sclerotium rolfsii* Sacc.), soil rot (*Rhizoctonia solani* Kühn[7]), and streak. The hornworm (*Protoparce sexta* Johan.) often destroys the foliage of the tomato plant and attacks the fruits as well.

A considerable number of diseases affect only the fruit. These are: Bacterial soft rot (*Bacillus aroideae* Town.[8]), Basisporium rot (*Basisporium gallarum* Molliard), blue mold rot (*Penicillium* sp.), buckeye rot (*Phytophthora terrestria* Sherb.), center rot (*Bacterium* sp.), Fusarium rot (*Fusarium* sp.), Isaria rot (*Isaria clonostachoides* Pritchard and Porte), Melanconium rot (*Melanconium* sp.), nailhead spot (*Macrosporium tomato* Cke.), watery rot (*Oospora lactis parasitica* Pritchard and Porte), and yeast spot (*Nematospora lycopersici* Schneider). In addition to these there are several important maladies conditioned by nonliving agencies. These are: Blossom-end rot, catface, chilling injury, cloudy spot, freezing injury, growth cracks, puffiness, sulphur dioxide injury, and sun scald. Heavy losses also result from the feeding of the cutworm (*Lycophotia margaritosa saucia* Hubner) and of the corn earworm (*Heliothis obsoleta* Fab.), which usually attacks the fruit at the stem end and opens the way for invasion by Rhizopus rot, bacterial soft rot, and watery rot. (*3*, *15*, *68*, *69*, *87*.)[9]

ALTERNARIA ROT (EARLY BLIGHT)

(*Alternaria solani* (Ell. and Martin) Jones and Grout; *Alternaria* spp.)[10]

OCCURRENCE, SYMPTOMS, AND EFFECTS

The leaf-spot and vine disease of tomatoes known as early blight is found to some extent in all tomato and potato growing regions. (See Potato, p. 4.) This disease as a rule does not cause extensive losses, but under favorable conditions may entail severe damage to the growing crops. Most serious losses are due to depletion of the foliage, with a subsequent reduction in quality and quantity of the fruit. *Alternaria solani* also attacks the fruits, usually entering through wounds, growth cracks, insect punctures, or lesions induced by other diseases. In this respect it is unlike *Macrosporium tomato*, which incites the characteristic fruit spot known as nailhead. (See Nailhead Spot.) Numerous other species of Alternaria, however, find ready entrance through wounds and like *A. solani* incite serious decays which are referred to as Alternaria rot. This decay is especially destructive during seasons when the fruit shows excessive

[5] Syn., *Phytomonas michiganensis* (E. F. Smith) Bergey et al.
[6] Syn., *Phytomonas vesicatora* (Doidge) Bergey et al.
[7] Syn., *Corticium ragum Berk. and Curt.*
[8] Syn., *Erwinia aroideae* (Town.) Holland.
[9] Italic numbers in parentheses refer to Literature Cited, p. 39.
[10] Throughout this publication the scientific name of the organism inducing a disease is shown in parentheses immediately following the heading giving the name of the disease. For a fuller statement regarding the rôle of these organisms, see footnote 11, p. 4.

wounds, shoulder bruises, and growth cracks. Stock held in the ripening rooms on the receiving market very often shows great loss due to Alternaria rot developing in the moist stem scar or following lesions produced by nailhead spot, Phoma rot, or blossom-end rot.

The decayed area is dark brown to black and usually extends into the interior of the fruit, causing black discolored seed cavities. When the fungus enters through the stem scar a black, moderately firm decay results and a brown discoloration of the vascular strands extending down into the fruit is noticeable. During transit and in the ripening rooms the humid atmosphere permits development of the brownish black mold over the surface of the lesions, the presence of which generally serves to distinguish this decay from all others. (Pl. 9, B.)

CAUSAL FACTORS [11]

The fungus *Alternaria solani*, which induces early blight, and which together with other Alternaria species induces Alternaria rot of tomato fruits, is present in most truck and vegetable growing regions, where the great numbers of spores produced by the fungi are blown about in the air. Under suitable moisture and temperature conditions these spores germinate and enter into the tissues of susceptible plants, producing leaf and stem blight and the fruit decay which is described as Alternaria rot. These fungi may be carried from season to season in the remains of dead plants, in the soil, or on related crop plants and weeds.

Tomato plants and fruits that are weakened or injured by any factor are more susceptible to infection by Alternaria than are normal plants. Both vines and fruits are especially subject to infection during the latter part of the growing season. Wet weather conditions followed by temperatures ranging between 75° and 85° F. favor the rapid development of this group of fungi.

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[11] In this publication the section "causal factors" under each disease comprises a statement of the complex of circumstances that determine the occurrence of the pathological phenomena under consideration; in other words, a discussion of all known antecedents of the consequences which are recognized as the disease. It is common usage among American plant pathologists to refer to the fungus or bacterium which enters into the condition complex of a pathological phenomenon as "the cause" of the disease. It should be borne in mind, however, that even in a disease induced by a foreign organism many other factors usually determine the occurrence of the disease. Among these are the conditions that govern the occurrence, abundance, and virulence of the foreign organism, foremost among which are (1) such external nonliving environmental factors as temperature, moisture, humidity, and food supply, and (2) the genetic constitution and other internal environmental factors of the organism itself. In addition, occurrence of the disease is conditioned by those factors which determine the resistance and susceptibility of the affected plant, namely, (1) the genetic constitution and other internal environmental factors, such as the age of the plant, and (2) the reaction of the plant during growth, harvest, transit, and storage to external nonliving environmental factors. Among these the most important are soil, weather, temperature, humidity, chemicals, composition of the surrounding atmosphere, and agents that cause injuries of any sort, especially those that break the protective tissues of the plant. For those pathological phenomena in which no foreign organism enters as a part of the causal complex, either the internal factors of the plant itself or the external nonliving environmental factors, alone or in combination, constitute the sole determining antecedents of the disease. The external nonliving environmental factors play a very important rôle in the pathological phenomena of plants during the growing, harvesting, transporting, and storage of the crop. As in diseases excited by foreign organisms, the significant external nonliving environmental conditions consist of physical, chemical, and mechanical factors, such as temperature, moisture, humidity, chemicals, composition of the atmosphere, and the like. When a specific foreign body, in the form of an organism, such as a bacterium, fungus, nematode, or insect, is the condition or agent which, by virtue of a precedent condition complex, is able to induce or incite a disease, the writers prefer to designate this specific type of disease factor or condition by the term "excitant" rather than by the expressions "the cause" or "causal organism," and to say that it "incites" or "excites" rather than that it "causes" the disease. In conformity with past usage in publications of the U. S. Department of Agriculture, however, the term "causal organism" is used rather than "excitant" in the body of this publication.

CONTROL

Destruction of diseased vines and fruits and general field sanitation are recommended to reduce the amount of inoculum in a given area. Spraying the young seedlings with 3–4–50 Bordeaux mixture while in the seed bed, and spraying the plants in the field with 5–5–50 mixture, will usually give satisfactory control of diseases induced by Alternaria species.

Careful handling of the tomatoes during harvesting and packing will reduce the number of wounds and bruises and consequently reduce the chances of infection and decay during transit and marketing. No fruits showing brown discoloration at the stem end or in wounds elsewhere on the fruit should be packed for shipment. (*61*, *65*, *88*.)

ANTHRACNOSE

(*Colletotrichum phomoides* (Sacc.) Chester)

Anthracnose of tomatoes has been reported from most of the tomato-growing regions, although it is a much more serious disease in the northern-grown crops than in the southern-grown or winter crops. It is essentially a rot of ripe fruit and consequently is of considerable importance when tomatoes are allowed to ripen on the vines for the local market or for canning purposes. Anthracnose is seldom important in green wrapped tomatoes shipped to distant markets, although occasionally found in the fruit ripening in transit and in the ripening rooms at the receiving markets.

In the early stages anthracnose is characterized by small, circular, slightly sunken spots of about the same color as the healthy surrounding tissue. The affected tissues appear slightly darker red than the rest of the tomato, and when the spots attain a size of about one-half inch in diameter, cream-colored to salmon-pink spore masses appear in the center. (Pl. 1, A.) With age, the spore-bearing areas of the spots may become somewhat dark or brownish black. Anthracnose lesions do not ordinarily penetrate into the fruits to a very great depth during transit or marketing, but they offer entrance for several secondary organisms which soon destroy the whole fruit. On fruits ripened on the vine, however, the spots may become over an inch in diameter and penetrate deeply into the pulp, causing serious loss in market-garden and canning crops.

Very little is known about the overwintering of the fungus or the relation of environmental factors to infection and disease production. Warm, wet weather favors the development and spread of the fungus, but since the original source of infection is unknown, there are no practical control measures to be recommended. (*2*, *14*.)

BACTERIAL CANKER

(*Aplanobacter michiganense* (E. F. Smith) E. F. Smith)

OCCURRENCE, SYMPTOMS, AND EFFECTS

Bacterial canker was first found affecting tomatoes near Grand Rapids, Mich., in 1909, at which time it was described as the Grand Rapids disease. Since it has been reported from numerous other tomato-growing localities, it has been renamed bacterial canker, and

at present it is known to cause more or less severe damage to the tomato crop in the following States: Michigan, Ohio, Tennessee, Wisconsin, Illinois, Iowa, Indiana, Mississippi, Texas, New Jersey, Connecticut, Maryland, Montana, Washington, Massachusetts, Georgia, New York, Utah, and California. So far the only tomatoes showing bacterial canker that have been received on the market have originated from Texas, Mississippi, and Tennessee.

The damage caused by this disease is twofold: The vines are weakened, with resultant poor setting of fruit or production of poor quality fruit, and the fruits themselves often become spotted and unmarketable. Losses ranging as high as 50 per cent have been reported from some localities.

Affected plants appear somewhat similar to those showing Fusarium wilt. At first the leaves at the lower part of the plant begin to wilt and turn brown, and then a progressive wilting and discoloration of the leaves above sets in. Frequently only one side of a plant is affected, so that it lies to one side quite noticeably. The bacteria are found in the vascular elements and progress upward through them. As the infection spreads to the cortex, gray to grayish-brown streaks appear on the surface of the stems; these streaks crack and form the open cankers characteristic of the disease. A cross section of the upper portion of an affected stem usually shows yellowish to reddish-brown discoloration of the inner phloëm, and the pith separates very readily from the wood.

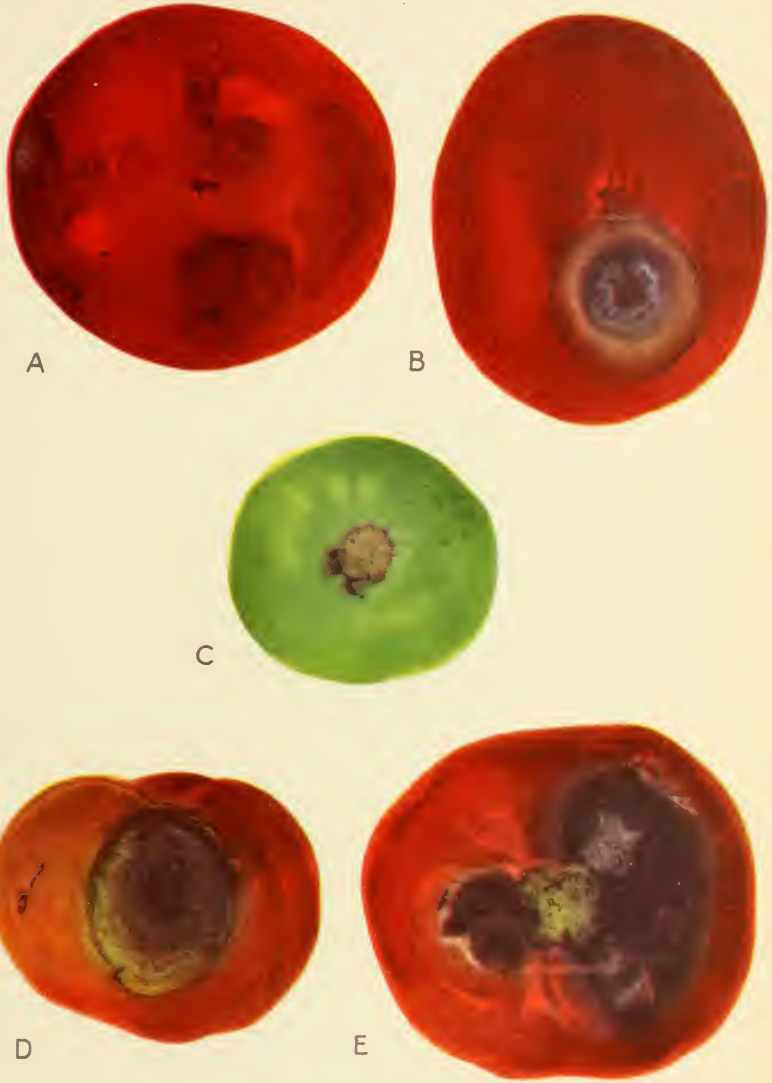
Affected fruits on the market show symptoms that are so characteristic as to make diagnosis easy. The lesions are usually small (one thirty-second to one-eighth inch in diameter) and definitely superficial. They occur first as minute white to light-brown slightly raised spots. As these enlarge the brown center becomes more prominent and surrounded by a characteristic white halo which does not show water-soaking. (Pl. 2, D, E.) With age the center becomes dark brown and may show a rift or slight lenticellike opening, but the definitely smooth, circular outline of the spot is maintained and the white halo is usually visible. While the individual spots seldom reach a diameter greater than one-eighth inch, aggregations of them frequently fuse to form large rough areas.

Tomato fruits are sometimes affected by the bacteria passing down through the vascular system. In such cases there is no external sign of disease unless the fruits are severely infected while very young, in which case they may become stunted and distorted. Neither the superficial spots nor the internally localized yellowish discoloration at the point of attachment of the seeds result in decay of the fruit.

CAUSAL FACTORS

The inciting agent (*Aplanobacter michiganense*) is carried over from year to year in and on the seed. Serious epiphytotics of bacterial canker are generally traceable to certain lots of seed or seedlings. It has been shown that the bacteria can survive both winter and summer conditions in Georgia in compost from diseased plants, but observations indicate that hold over in the soil is not likely to be important.

As the bacteria work up through the vascular system toward the upper part of the plant they spread through the cortex to the



TOMATO FRUIT DISEASES

A, Anthracnose rot; B, ring rot (Melanconium); C, Phoma rot, early stages; D and E, Phoma rot, later stages

TOMATO FRUIT DISEASES

Very early (A), medium (B), and late (C) stages of bacterial spot; D and E, bacterial canker in various stages

epidermis. When the affected surface tissue cracks the bacteria are set free, and under favorable weather conditions they spread infection to other leaves, stems, or fruit. Wet weather conditions favor the spread of the bacteria and enable them to remain alive until they find entrance into the plant through stomata or into young fruits through the delicate surface hairs.

CONTROL

The selection of seed from clean fields is to be most highly recommended for the control of the bacterial canker. Seed treatment with mercuric chloride is helpful in destroying the surface bacteria, but since some of the bacteria are usually underneath the seed coat, this treatment can not be completely relied upon. In the tests made so far no resistant varieties have been found. (*10*, *11*, *12*, *78*.)[12]

BACTERIAL SOFT ROT

(*Bacillus aroideae* Town.)

Bacterial soft rot of tomatoes occurs in the field, in transit, and in ripening rooms. Green fruit is especially susceptible; ripe fruit showing lesions usually became infected while green.

The decay affects various vegetables and has all the characteristics of the bacterial soft rot caused by *Bacillus carotovorus* Jones.[13] It is induced by an organism that differs from *B. carotovorus*, in that it rots beet roots, cauliflower curds, kohlrabi, and sweetpotato roots. It also affects muskmelons, carrots, cucumbers, eggplant fruits, potatoes, parsnips, peppers, onions, radishes, and cabbage. The depressed, water-soaked areas forming the first symptoms of this rot in tomato fruits are sharply delimited from the healthy tissues. (Pl. 9, C.) The interior surface of the lesions becomes opaque in a short time, but there is always a narrow water-soaked margin. In 3 to 10 days the entire fruit is converted into a soft, watery, colorless, foul-smelling mass. Before final dissolution of the tissues the fruit wrinkles and often cracks. The affected fruits are known as " water bags " and often burst, spilling the foul-smelling interior.

Like the soft rot caused by *Bacillus carotovorus*, it progresses rapidly. Inoculated fruit shows lesions within 24 hours. At 59° F. about 17 days are required to rot green tomato fruits completely, while at about 86° only 7 days are required. Pepper fruits may be completely rotted in 5 days, eggplant in 4 to 5 days, muskmelons in 3 days, and potatoes in 7 to 21 days.

It is reported that spraying with Bordeaux mixture reduces the rot in the field. (See Potato, Bacterial Soft Rots, p. 6.) (*47*, *90*.)

BACTERIAL SPOT

(*Bacterium vesicatorium* Doidge)

OCCURRENCE, SYMPTOMS, AND EFFECTS

Bacterial spot, also known as canker, scab, smallpox, and by other names, is a serious disease of tomatoes and has been reported from

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[12] FENNER, L. M. BACTERIAL CANKER OF TOMATO. U. S. Dept. Agr., Bur. Plant Indus. Plant Disease Rptr. 14: 134–140. 1930. [Mimeographed.]

[13] Syn., *Erwinia carotovora* (Jones) Holland.

several States, but seems to occur most frequently and seriously in Indiana, Michigan, Georgia, Tennessee, Texas, Mississippi, Florida, and Mexico. Practically all varieties of tomatoes are affected. It also occurs on peppers. (See Peppers, p. 31.)

Seedlings are attacked, and this sometimes leads to losses, but the chief economic importance of this disease is due to its attack on the fruits. Affected fruits are blemished and disfigured, but show no decay unless secondary organisms follow. Shipping tests indicate that the entire development of spots on the fruits takes place in the field while the tomatoes are growing. No new spots have ever been found to develop on tomatoes during transit, and no measurable enlargement of the spots present at shipping time has ever been detected.

On fruits the young lesions appear as dark raised dots, sometimes with a narrow water-soaked border. (Pl. 2, A.) The enlarged spots form black, elevated scabs with irregularly lobed margins. (Pl. 2, B, C.) The centers become slightly sunken, brown, and corky by the time the lesions reach a diameter of one-eighth of an inch or larger. As a rule the lesions do not penetrate into the pulp of the tomato, but remain superficial, as is true also of the same disease on pepper.

On the leaves the first symptoms are very small, water-soaked, translucent spots, which upon enlargement turn black in the center and become distinctly sunken on the lower side of the leaf. The leaf lesions are irregularly circular in outline and have a narrow, yellowish, translucent border. Severely infected leaves turn yellow and finally become brown and dry. When the stems and petioles become infected, black elongated lesions are produced. Affected cotyledons turn yellow prematurely.

CAUSAL FACTORS

Bacterium vesicatorium, which induces this disease, overwinters on seed produced in infected fruit and probably also in the soil. When infected seed is planted the bacteria have access to the tender tissues of the seedling, especially the cotyledons. From the primary spots the bacteria are disseminated by rain, by spattered and blown soil, and by insects. The pathogene enters the leaf tissues through the stomata. Although it apparently does not need artificial wounds to enter the green fruits, it is thought that infection may take place through fine surface hairs on immature fruit. Insect punctures are a common mode of entry. Often in the center of lesions the slits made by insects (stink bugs) can be seen very plainly. Green fruits are readily infected, but ripe fruits resist infection. The organism is favored by moderately high temperatures (77° F.) and can resist drying for long periods.

CONTROL

Since the pathogene can overwinter on seed, it is advisable to soak seed for five minutes in a solution of corrosive sublimate (1 to 3,000) and then wash it in running water for 10 or 15 minutes. (*18*, *21*, *28*, *30*, *35*.)

BASISPORIUM ROT

(*Basisporium gallarum* Molliard)

Apparently *Basisporium gallarum* affects tomato fruits only during transit and while in the ripening rooms, although little is known regarding the distribution of the disease. During November, 1919, on the Chicago market, California tomatoes were found affected with Basisporium rot. Both ripe and green fruits are subject to decay when wounded. On plate cultures the causal organism is able to make growth at temperatures as low as 48° and as high as 95° F., but fruit infection is prevented by refrigeration at temperatures below 50°. Ripe tomatoes held at 70° will develop lesions 2 inches in diameter and over an inch deep within four days after infection takes place.

In green fruits, dark-green water-soaked lesions are produced. Ripe tomatoes are more susceptible to infection, however, and on them soft, deep-red, blisterlike spots are produced. No surface mycelium is produced unless the fruit is cracked or the skin broken open. An abundance of pale smoke-colored mycelium is developed in a humid atmosphere, and small spherical jet-black spores are barely visible to the naked eye.

Careful handling of fruits to avoid excessive wounds is recommended for control of this disease. (*56.*)

BLOSSOM-END ROT

OCCURRENCE, SYMPTOMS, AND EFFECTS

Few if any tomato-growing regions are free from blossom-end rot. Certain varieties have been reported resistant to this trouble, and some breeding experiments have indicated that resistance to it may be transmitted from parent to progeny, but so far no very satisfactory strains have been developed. Varieties said to be resistant in some localities are not resistant in others. Environmental factors seem to determine its appearance and abundance. Either continued excessive watering or a sudden check in the water supply may produce the disease. The effects of drought are more pronounced at the time of maximum fruit expansion. The stage of development of the fruit seems to be an important factor, since fruits of a certain size may be severely affected, while the younger and older fruits may entirely escape. Soil and air temperatures are also important factors and according to some investigators should be considered almost as important as soil moisture.

The disease not only seriously blemishes fruit but also predisposes fruit to decay by such secondary organisms as Alternaria, Fusarium, Rhizopus, and bacteria, in the field and during transit and marketing. Since first symptoms do not appear until three to six days after the critical disturbances of moisture or temperature, fruit is sometimes packed which appears sound but which develops lesions and rot later on.

In the early stages the disease appears as small spots at or near the blossom end of the tomato. At this stage the diseased area looks like a bruise and is water-soaked and dark green in color. As the spots increase in size the affected tissues collapse and become firm,

leathery, and brown in color. (Pl. 3, A.) Sometimes the collapsed area is so sharply marked that the lesion appears as a distinct depression (pl. 3, B); generally, however, it results only in a flattening of the end of the fruit. Usually after the tissues have sunken and changed to a dark-brown color the vascular strands can be seen radiating from where the blossom was attacked. These flat, dry lesions often cover the whole blossom end of the fruit, but they are very shallow and are more a blemish than a rot, unless secondary organisms invade the dead tissues. Alternaria is the most important decay-producing fungus following blossom-end rot.

CONTROL

No satisfactory control measures have been worked out. The water supply should be regulated whenever possible, and only varieties best suited to the soil and climatic conditions should be planted. On account of the danger of secondary decay following blossom-end rot in transit and in ripening rooms, it is unwise to ship appreciably affected fruits. (*7*, *80*, *82*.)

BUCKEYE ROT

(*Phytophthora terrestria* Sherb.)

OCCURRENCE, SYMPTOMS, AND EFFECTS

Rot of tomato fruits is induced by several species of Phytophthora, of which the following have been reported as pathogenes: *P. infestans* (Mont.) DBy. (see Late Blight Rot, p. 17), *P. terrestria*, and *P. mexicana* Hotson and Hartge. Of these, *P. infestans* and *P. terrestria* probably are the most important. *P. terrestria* apparently attacks only the fruits, and the decay it causes is known as buckeye rot. This disease is usually restricted to tomatoes in southern regions, although it has been reported as far north as Indiana. The decay occurs in the field and also in transit and in ripening rooms.

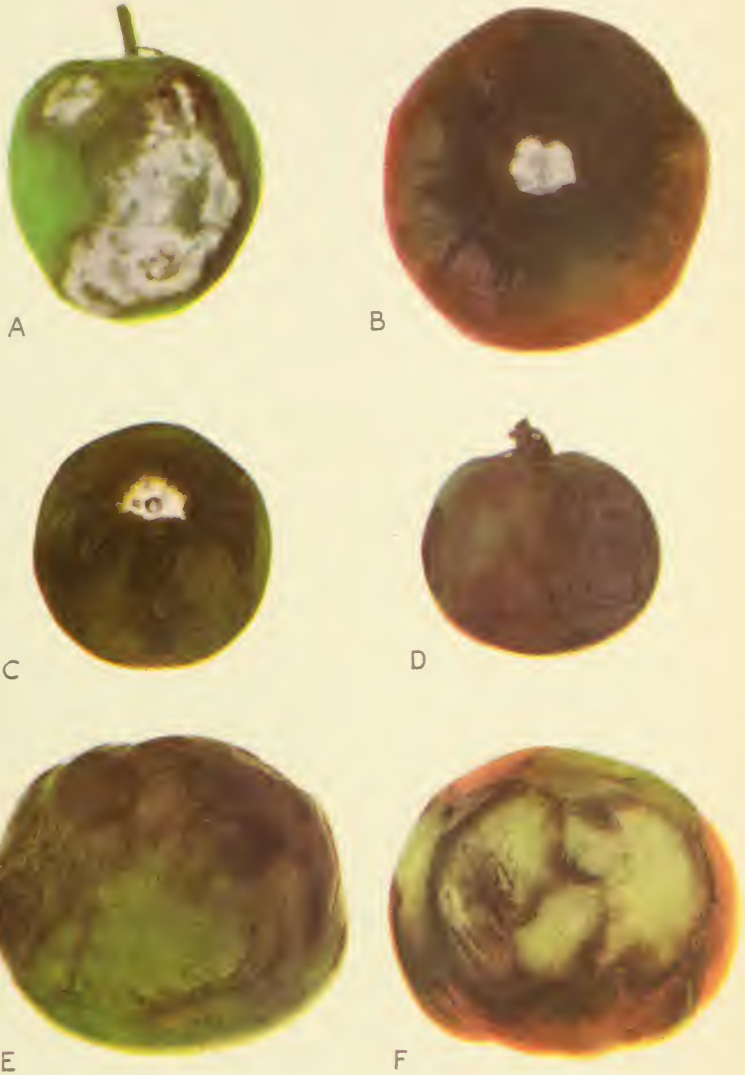
The term buckeye rot is very appropriate, because in color and in its surface appearance the lesion often resembles a horsechestnut. (Pl. 4, E, F.) The rot is at first firm and hard, the lesions are grayish green to brown, and the surface is uneven and sunken in spots. (Pl. 4, E.) The border of the lesions is not sharply defined or regular, but often merges into water-soaked, slightly bleached tissues. Sometimes the entire lesions appear merely water-soaked, but at times they are marked off in wide zones with brownish more or less circular discolorations. These concentric rings, which are not always apparent, present a very striking appearance. (Pl. 4, D.) Ordinarily there is little or no surface mycelium in evidence, but if the tomatoes are held in a humid atmosphere there will appear on the surface of the lesion a white, fluffy mycelium which when wetted becomes matted and tough.

CAUSAL FACTORS

Phytophthora terrestria is a soil fungus which does not become a disease-producing factor except in warm, humid, or wet weather. Infection takes place when fruit is in contact with wet soil or when it is spattered with infested soil. The fungus penetrates the un-

TOMATO FRUIT DISEASES AND ABNORMAL CONDITIONS

A and B, Blossom-end rot; C, catface; D, growth cracks; E, skin checks and cracks



TOMATO FRUIT DISEASES

A, B, and C, Late blight rot; D, E, and F, buckeye rot

broken skin and consequently may affect any part of the fruit. It develops in transit and in the ripening rooms, frequently appearing in fruit that was passed as sound at the time of packing. It is able to penetrate wrappers and thus to attack neighboring fruits by contact infection.

CONTROL

Staking the plants in the field to hold the fruits up from the soil helps greatly to control this disease. Losses in transit can be reduced by carefully sorting out all diseased tomatoes at time of packing. (*36*, *64*, *66*, *75*, *76*, *88*.)

CATFACE

Catface is characterized by misshapen or puckered blossom ends of the fruit. The condition apparently involves imperfect development of certain areas which at maturity are represented by an irregular, leathery scar. (Pl. 3, C.) There seems to be a varietal difference in the tendency of varieties to develop catface. It lowers the market value of fruit, because it disfigures it and also provides easier entrance for secondary organisms.

CENTER ROT

(*Bacterium* sp.)

Center rot has been reported as affecting tomatoes in Texas, Nebraska, Michigan, and Maryland. Since, however, several bacteria and some fungi seem to be involved in inciting the symptoms covered by the descriptive name center rot, it is to be expected that this type of decay may be found under favorable seasonal conditions in many other localities.

In its early stage the disease is characterized by a brown spot or a dark ring around and under the stem. As the fruit turns pink the stem end becomes dark brown in color, and a hard brown center is evident when the fruit is cut. Frequently this brown center extends from stem end to blossom end, and occasionally some of the seeds are discolored. The slime which is so common in other bacterial rots is absent in center rot.

Whether this brown center is caused by fungi or bacteria, infection takes place at the stem end. In most instances, probably, one type of organism finds entrance into the stem scar, and its invasion opens the way for other organisms. Most tomatoes on the market that have shown this type of decay have been affected by bacteria. No control measures are known. (*8*, *9*.)

CLOUDY SPOT

The trouble known as cloudy spot has been found chiefly in Florida tomatoes. So far as is known, it is strictly a blemish of the fruit and has never been observed to cause great loss except on individual plants here and there in the field. No causal agent has been discovered.

The characteristic symptoms are whitish, irregular-shaped blotches and spots appearing just underneath the epidermis of the fruit. Cutting discloses the fact that the white blotches are made up of spongy,

silvery-white cells, which have quite evidently lost their moisture. No decay or further discoloration of the tissue takes place. In some instances a slight scar may appear over the blotch, suggesting the possibility that an insect puncture caused the blemish, but in most cases the spots are too large, and their association with the vascular elements in the walls of the fruit indicates that the trouble is due to physiological disturbances within the plant. (*88.*)

FREEZING AND CHILLING INJURY

As in other vegetables, freezing injury does not occur in tomato fruits unless ice is formed in the tissues. However, unlike some, such as cabbage, lettuce, and onions, tomatoes do not tolerate freezing and thawing, so that ice formation almost invariably means destruction or serious injury to tomato fruits.

In the tomato, as in other plant tissues, the freezing point and the killing temperature are lower than the freezing point of water. A series of experiments with ripe and green fruit of various varieties of tomatoes has shown that the average freezing point is 30.38° and 30.40° F. for ripe and green fruit, respectively. The lowest minimum was found in the New Glory variety, in which ice formed at a temperature of 29.63°, whereas the highest maximum occurred in the John Baer variety at 30.9°.

Exposure of tomato fruits to a temperature of 30° to 31° F. does not necessarily imply that ice will form, since tomatoes have been exposed under laboratory conditions to 25° for 18 hours without injury, when precautions were taken to prevent ice formation. As in other tissues, the rate at which tomatoes are cooled is a factor in determining how far they can be undercooled.

While in the frozen condition, ripe and green tomato fruits may appear glassy or candied, or dull colored. Upon thawing, the tissues of ripe fruit almost invariably break down and become watery. This watery condition usually spreads to the parts not directly involved in the freezing. Bacteria almost invariably invade the tissues and cause foul-smelling decays. Green fruits, unless frozen throughout, may thaw out without complete collapse. In these the water liberated in thawing may in part go back into the tissues and in part evaporate, if the killed area is not too large. As a result, collapsed, shrunken areas are produced in which the vascular tissues often are browned.

Low temperatures are especially significant for tomatoes, because the crop, unless marketed locally, generally is picked before the green color is replaced by the required red. It is so universally believed that low temperatures (even above the freezing point) chill and injure tomatoes that they are rarely sent under refrigeration unless they are pink or red. "Chilling" of green fruit is held responsible not only for failure of tomatoes to turn red or to develop good flavor, but also for excessive decay and drying out in the ripening rooms.

It has been demonstrated experimentally, however, that tomato fruits of the Globe variety that are mature green or just turning can be exposed to low temperatures just above the freezing point of tomatoes (30.5° to 31.5° F.) for five days without any injury whatever. They may even be undercooled to 26.5° to 29° for short periods and escape injury if ice formation is prevented. In another set of experi-

ments tomatoes exposed to 32° to 36° for eight days subsequently ripened with normal color and flavor but more slowly than those not exposed to low temperatures. Other tomatoes exposed to 40° for less than 11 days and to 50° for less than 14 days ripened normally. On the other hand, if exposed to these temperatures for longer periods they tend to soften and break down and may either fail to ripen or ripen with pale color and flat insipid flavor.

Undoubtedly a great deal of the loss in ripening rooms is due to the fact that tomatoes are picked while too immature and consequently lose water excessively or decay without developing good color and flavor.

Although tomato fruits are considered much less hardy than cabbage or lettuce, the temperature at which they freeze is lower than that of cabbage or lettuce, for which the average freezing points are 31.18° and 31.20° F., respectively. These figures do not mean that these commodities will freeze when exposed to the temperatures listed. They merely mean that when the tissues freeze they will register the temperatures indicated and that the air temperature must be at least as low as those given. Generally, temperatures considerably below these will not cause ice formation if the exposure is short, and even long exposure may not cause ice formation or freezing. It must also be borne in mind that ice formation does not necessarily mean death or visible injury to such tissues as those of cabbage, onion, lettuce, and turnips, whereas prolonged exposure to temperatures not low enough for ice formation may be sufficient to cause injury in tomato fruits. (*20*, *63*, *91*.)

FUSARIUM ROT

(*Fusarium* spp.)

Fusarium rot is likely to occur in tomatoes from any section. Several species and strains of the Fusarium fungus appear to be able to incite decay in tomato fruits, provided a wound or a lesion of some other disease is available as a portal of entry. This decay is generally not important, however, except in fruits turning color or ripe fruits during transit and marketing.

The secondary nature of the Fusarium decay is ordinarily quite obvious. The affected tissues are water-soaked and slightly sunken, and a moderately fine, white, cream-colored or pinkish mycelium is evident over the center of the lesion. (Pl. 9, D.) The decay progresses rapidly, causing complete destruction of ripening tomatoes within four days. In the warm, humid atmosphere of the ripening rooms on the receiving markets this secondary decay often causes considerable damage by developing in wounds at the stem scar or at the blossom end.

FUSARIUM WILT

(*Fusarium lycopersici* Sacc.)

Wilt is one of the most serious field diseases of tomatoes. It affects the marketability of fruits only indirectly, however, by causing undersized, poorly colored, and poorly flavored tomatoes. The disease occurs in all the warmer regions, where the pathogene, which is one of the soil fungi, may remain in the soil for several years,

once it gets in. Long, hot seasons in which the soil temperature becomes high are especially favorable for the development of wilt. The fungus can not grow at temperatures above 90° F., usually does not cause trouble in the field below 68°, and grows best at about 82°. Variation in the susceptibility of varieties to Fusarium wilt has led to the selection and breeding of resistant strains. No variety has been found entirely immune, but those showing resistance or tolerance are proving satisfactory in certain localities.

The disease is a typical Fusarium wilt. (See Potato, Fusarium Wilts, p. 25.) At first a few of the lower leaves wilt, turn yellow, and die; then, as the disease progresses, successive leaves wilt, until the whole vine is dead. Often only one side of the plant is affected, leading to lopsided development or one-sided wilting. The fungus works up through the roots, follows up the vascular tissue into the stem, and sometimes goes into the young, developing tomato fruits. Dark or brownish discoloration of the vascular tissue is characteristic.

Since the fungus is carried over in the soil, a 3-year crop rotation is advised for badly affected regions. Seed-bed sanitation should be practiced and resistant varieties should be used. The Marglobe, Norton, Marvel, Break o' Day, and Columbia are among the most desirable. (*16*, *22*, *34*, *51*, *70*, *74*, *80*, *89*.)

GRAY-MOLD ROT

(*Botrytis* sp.)

Gray-mold rot is one of the common diseases of fruits and vegetables raised under moist conditions. It is found abundantly in humid greenhouses, and in trucking regions where heavy dews or fogs prevail. On the tomato, however, it is one of the minor diseases, seldom being of economic importance.

The fungus usually establishes itself on plants through leaf scars or other dead tissue, whence it progresses into the living tissues, producing water-soaked, greenish-brown lesions. On the leaves and stems these lesions may be severe enough to result in wilting and death, but ordinarily this is not of much consequence.

On the fruits the fungus usually enters through the stem end or the blossom end or through growth cracks. Decay progresses rapidly in either green or ripe tomatoes. The lesions produced on green fruit are grayish green, water-soaked, and generally quite definite in outline. The most characteristic sign of this disease is the presence of the gray to grayish-brown mycelium and spores of the fungus over the center of the lesion, or where the epidermis has been ruptured. (*17*, *19*, *83*.)

GREEN-MOLD ROT (LEAF MOLD)

(*Cladosporium fulvum* Cke.)

OCCURRENCE, SYMPTOMS, AND EFFECTS

Leaf mold has been known chiefly as a greenhouse disease of tomatoes, but in recent years it has been found to be involved in considerable damage to plants in the fields and in transit on fruit as green-mold rot, especially in stock shipped from California and Mexico. A fruit rot of greenhouse tomatoes has also been reported as destructive during some seasons in Indiana.

On the leaves the first signs of disease are small, irregular, yellowish spots visible on the upper side, and a velvety, mouse-colored or greenish-gray mold on the lower side of the leaflets. Later the spots may become blotchlike, or several small spots may merge to form large areas of yellowish-brown discoloration on the leaflets. In wet seasons this disease may lead to considerable damage to the foliage, but it never completely destroys a crop.

The time and mode of infection determine, to a large extent, the type and the severity of the decay produced in the tomato fruit. When the fungus enters the green tomato through slight skin abrasions or insect punctures, the spots produced are usually tan to greenish brown, somewhat leathery, and slightly sunken, whereas on ripening fruits the lesions are distinctly sunken, the center being greenish black to black, and the border tan to grayish tan. (Pl. 5, B.) The spots vary from one-eighth to one-half inch in diameter and are characteristically circular in outline. On the ripening fruits during transit and on the market the centers of the larger spots become jet black and are so smooth that they have a polished appearance. (Pl. 5, C.) Under very humid conditions the fungus sometimes comes to the surface and is in evidence as a fine, greenish, powdery mold. (Pl. 5, A.) Most lesions do not extend much over one-eighth inch in depth. The decaying tissue within is tan to grayish black and spongy, and can be lifted from the surrounding healthy tissue with the point of a knife.

Green mold has been observed on the market causing considerable decay following nailhead spot in Mexican stock. In such cases the characteristic tan nailhead spot is prominent in the center, while the surrounding tissue is jet black and has a polished appearance. These spots vary from one-fourth to one-half inch in diameter, but seldom penetrate through the wall of the fruit. The tan to grayish-black color and the spongy texture of the decaying tissue is maintained as in other types of green-mold rot, whereas when Alternaria or Macrosporium species follow nailhead spot the decay produced is semiwatery, brownish black in color, penetrating into the seed cavity, and a brownish-black surface mold is usually visible.

Greenhouse tomatoes showing fruit decay incited by the green-mold rot organism generally show decidedly black lesions extending out from the stem end, the infection apparently coming from the vine and entrance into the fruit being made only through the stem. These lesions sometimes involve almost one-third of the fruit. Occasionally there is another type of infection on the sides of the fruit which results in producing reddish-black blotches or a lacy network of dark mycelial strands just underneath the epidermis. This blemish is only skin deep and apparently does not develop into a decay such as that produced when entrance is made through the stem end.

CAUSAL FACTORS

The inciting organism (*Cladosporium fulvum*) is widely distributed and is especially in evidence during wet weather. This fungus appears able to exist on living and dead plants of many kinds, consequently there always seems to be an abundance of inoculum for producing infection in tomatoes when favorable weather conditions prevail. The fungus grows most rapidly at approximately 77° F., but

can grow at temperatures down to 48° and as high as 86°. The most important limiting factor in its development is moisture.

CONTROL

Since most if not all of the green-mold decay found on market tomatoes appears to have originated in injuries of some kind, it seems that careful handling during harvesting and packing may reduce the amount of decay that follows during transit and marketing. In transit and in the ripening rooms as dry air as is consistent with normal ripening should be maintained. Control of the moisture supply and ventilation in the greenhouse gives excellent control of this disease.

The fungus is known to live in and on the seed coat and may be introduced into the seed bed in this manner. To avoid this possibility it is advisable to use only seed known to have come from healthy fruits. (*24*, *25*, *32*, *45*, *49*, *80*.)

GROWTH CRACKS

Growth cracks consist of checks or deep ruptures or cracks, which either radiate from the stem end or are arranged somewhat concentrically about the shoulders. (Pl. 3, D.) In the field these ruptures often develop slowly enough so that some healing occurs, but they are easily broken in handling later. The cracks often extend to the pulpy part of the fruit and consequently provide easy access for decay-producing organisms.

Development of these ruptures seems to result from active, rapid growth following a period of slower growth or of quiescence. Continual rapid growth also produces them.

Shallow checks and cracks frequently occur in the skin over the shoulders and top portion of tomato fruits grown under some conditions. (Pl. 3, E.) These are sometimes referred to as sand blast or insect injury, but the cause of such blemishes is not well understood. In some varieties of tomatoes there are certain cells or patches of cells in the skin which appear brown and distorted. The cells and cuticle above these areas sometimes crack as the fruit expands during growth, and these external blemishes are quite apparent when the injured cells become discolored. These injuries frequently open the way for such decay-producing organisms as Alternaria and Phoma. (*33*.)

Tomatoes showing fresh growth cracks should not be shipped.

ISARIA ROT

(*Isaria clonostachoides* Pritchard and Porte)

Isaria rot has been reported in greenhouses and fields in the vicinity of Washington, D. C. Little is known regarding its distribution. The fungus apparently does not attack tomato plants, but is able to produce infection in unwounded as well as wounded fruits. The minimum temperature at which infection of fruits will take place is approximately 57° F.; some infection may be produced at temperatures as high as 90°, but the optimum is about 84°. Fruits affected with Isaria rot have never been observed on the market.

TOMATO FRUIT DISEASES

A, B, and C, Green mold rot (Cladosporium); D, Rhizopus rot

Affected fruits are characterized by a white, cottony surface mycelium that later changes to pink or pale orange and becomes somewhat granular as sporulation takes place. In a dry atmosphere, however, very little mycelium is apparent. Sometimes the fungus develops in the interior of the tomatoes without much disintegration of the tissues and then appears upon the surface later. Affected tissues are firm and tough when cut. No unpleasant odor is produced. (*52*.)

No control methods have been devised.

LATE BLIGHT ROT

(*Phytophthora infestans* (Mont.) DBy.)

OCCURRENCE, SYMPTOMS, AND EFFECTS

Late blight rot is similar to late blight in potatoes (see Potato, p. 30) and apparently is induced by the same fungus. It has been reported from a number of States, but is generally not of economic importance except in California, Virginia, West Virginia, and Pennsylvania. Shipments received from Mexico have also shown this disease. Late blight is often found in tomatoes planted in close proximity to potato fields, or in crops following potatoes, but this association is not always necessary. When susceptible crops are grown, such as the potato and tomato, in regions whose temperature and moisture conditions are favorable to the growth and spread of this fungus, late blight is one of the most destructive diseases known. In many instances the whole crop is lost, and in mild epiphytotics of this disease it is not unusual for 20 to 50 per cent of the fruits to show decay by the time they reach the market.

All of the aboveground parts of the tomato plant are susceptible to attack by the late-blight fungus. Large water-soaked greenish-brown to black blotches are produced on the leaves and frequently on the stems. During wet weather a fine white downy mildew is formed on the under surfaces of affected leaves, as well as on the stem lesions. In severe epiphytotics of this disease the vines are completely killed within a few days and the field appears as if a heavy frost had occurred.

Tomato fruits are apparently susceptible to attack by this fungus during all stages of their development. Small tomatoes less than 1 inch in diameter often become completely decayed while hanging on the vine, and fruits of larger size showing all stages of decay are readily found in the field during epiphytotics of the disease. In practically all instances the decay starts at the stem scar and progresses down through the tissues, producing a watery brown breakdown of the internal as well as the external tissues. The first visible symptom of decay on the fruit is a small greenish-brown blotch less than one-fourth inch in diameter at the edge of the stem scar. Pressure applied by moving the thumb over the blotch toward the scar causes drops of water to come out at the edge of the scar. As the decay progresses the tissues become more water-soaked and there is a change from greenish brown to brown without any definite markings and generally without visible evidence of the fungus. If the decay is well advanced and the fruits are in a moist, well-pro-

tected place, the fungus develops on the surface of the decaying tissues and is in evidence as a fine white mildew. (Pl. 4, A.)

Lesions that develop during transit under the humid conditions within the car and under the protection of the wrappers generally show as large greenish-brown water-soaked blotches with a fine white mildew especially prominent over the stem scar. (Pl. 4, B, C.)

CAUSAL FACTORS

The amount of damage caused by late blight is directly related to the weather conditions. When temperature and moisture are favorable for the development of the inciting organism, *Phytophthora infestans*, it is one of the most destructive fungi known. Most serious losses are sustained during wet seasons when the nights are cool (50° to 60° F.) and the days moderately warm (60° to 75°).

A mean daily temperature above 75° checks the disease. The spores of the fungus are killed within a few days during dry weather when the temperature reaches 80°. Consequently, in regions where the temperature is high and the air is dry for the greater part of the time, late blight is not an important disease. It is more prevalent in regions of high altitude, such as the mountainous sections of Virginia and West Virginia, and in coastal regions, such as southern California, where fogs and rains are frequent.

During periods in which there is an abundance of atmospheric moisture to favor spore production and germination, the tomatoes harvested from fields showing any appreciable amount of late blight are generally subject to a great amount of decay in transit, even though they show no evidence of disease at the shipping point. The fungus usually enters the tomatoes through the stem scar, but it may enter through a wound on any part of the fruit. After infection has occurred about five days are required for the decay to become visible. Shipping tests have shown that even the most carefully selected tomatoes from blighted fields may show over 8 per cent decay at the end of a 6-day transit period, and that tomatoes commercially graded and packed from similar fields may show as high as 32 per cent of decay on arrival at the receiving market. Tomatoes in which there was no visible evidence of decay when packed often develop spots varying from one-half to 1½ inches in diameter during a 6-day transit period. Visible spots present on fruits at the shipping point generally increase over an inch in diameter within six days, the average transit period from California fields to mid-western markets. Test shipments indicate that there is but little spread of the disease from decaying to healthy fruits during transit. Such new spots as have been observed to develop by contact during transit were mainly at the stem end of the tomatoes and were about 2 inches in diameter.

CONTROL

Late blight may be kept under control in the fields if the weather permits a thorough spray program to be followed. Best results are generally obtained by use of Bordeaux mixture or some of the copper dusts.

Tomatoes from fields showing an appreciable amount of leaf and stem blight should not be shipped until after they have been held for a few days to allow for development of decay and for subsequent

sorting and grading. The amount of decay developing during transit and marketing in stock harvested from blighted fields may be greatly reduced by immersing the tomatoes for two minutes in a sterilizing wash (1 part commercial formaldehyde to 300 parts of water) and then allowing them to stand for four or five days before sorting and packing for shipment. (*4*, *23*, *31*, *38*, *48*, *58*, *62*, *79*.)

MELANCONIUM RING ROT

(*Melanconium* sp.)

Melanconium ring rot is reported from Cuba, Ohio, and Texas and is known to affect tomatoes in the greenhouse; otherwise it is of little economic importance. Affected fruits decay during transit and ripening, and the lesions provide openings for secondary decay-producing organisms.

On the market, tomatoes showing this disease are characterized by large, flattened, conspicuous lesions marked by brown concentric rings. In the center the spots vary from light brown to dark brown in color and usually show acervuli by the time they reach a diameter of one-half inch or more. (Pl. 1, B.) In a humid atmosphere the greenish to black spore masses may be observed in the center of the lesions, and frequently these spores germinate, producing a fine white mycelium. The lesions produced are usually rather firm, but the fungus penetrates into the seed cavity, sometimes causing a soft rot, and producing dark spore masses within.

Fruits affected in the greenhouse show small irregular brownish spots about one-eighth of an inch in diameter, which later become dark and finally black. Bordering these lesions the tissues are sunken or depressed and the line of demarcation between diseased and healthy tissue is sharply defined. The surrounding skin of the ripened fruit may be slightly yellowish, but usually it is normal in color.

The pathogene, *Melanconium* sp., produces innumerable spores in slimy masses on the larger lesions. These spores are scattered largely by insects and spattering rain drops. Under favorable temperature (72° to 80° F.) and moisture conditions they germinate within a few hours and are capable of infecting both green and ripe fruits. Infection takes place in the field independently of wounds, and the lesions enlarge during transit.

No control methods have been developed for this disease. (*84*.)

MOSAIC (MOTTLING)

OCCURRENCE, SYMPTOMS, AND EFFECTS

Mosaic in tomatoes, as in other members of the nightshade family, is often very conspicuous in the growing plants, and in severe cases the photosynthetic capacity of the plant is so interfered with that dwarfing and great reduction in set of fruit result. The most characteristic symptom of mosaic is the mottling and crinkling of the leaflets. The light yellowish-green and dark-green irregular areas in the leaf-blade tissues may be scarcely visible or may be very pronounced. Great distortion of the leaflets often occurs. Sometimes the yellow areas die and turn brown. Similar brownish streaks may be produced on the leaf petioles and stems also, but these symptoms are not usually in evidence.

The fruits on plants affected by mosaic may or may not show signs of disease. The conditions under which the plants are grown and the kind or kinds of virus present determine the symptoms manifested. In some tomatoes showing a great amount of mosaic in the foliage, the fruits are externally without blemish, while fruits from similar appearing plants may show marked mottling. (See Streak, p. 27, and pl. 7, D, E.) In some types of mosaic the fruits become distorted, the partitions are thickened and raised, and an underdevelopment of the placentae contributes to creating a puffy condition of the fruit.

CAUSAL FACTORS

The cause of mosaic is not known; no organism has ever been proved to be the inciting agent. It is known that the infective principle (virus) is present in the juices of diseased plants, and that when some of this juice is introduced into a healthy plant this plant soon gets the disease. The virus is carried from plant to plant chiefly by sucking insects, by pruning, or by handling the plants in any way that causes injury and makes possible the entry of the mosaic virus. The virus is carried over from season to season in related plants such as horse nettles and groundcherries. It is not carried over in the tomato seed.

The potato mosaic virus will affect tomatoes, and it is probable that other viruses affecting the Solanaceae may be found on the tomato.

CONTROL

As control measures, the tomato field should be kept free from weeds, especially horse nettles and groundcherries. Tomato seedlings that show evidence of mosaic should not be used. Spraying to control insect carriers of mosaic may prove of some value under certain conditions. No commercial varieties of tomatoes have proved to be resistant to mosaic. (*1*, *13*, *26*, *29*.)

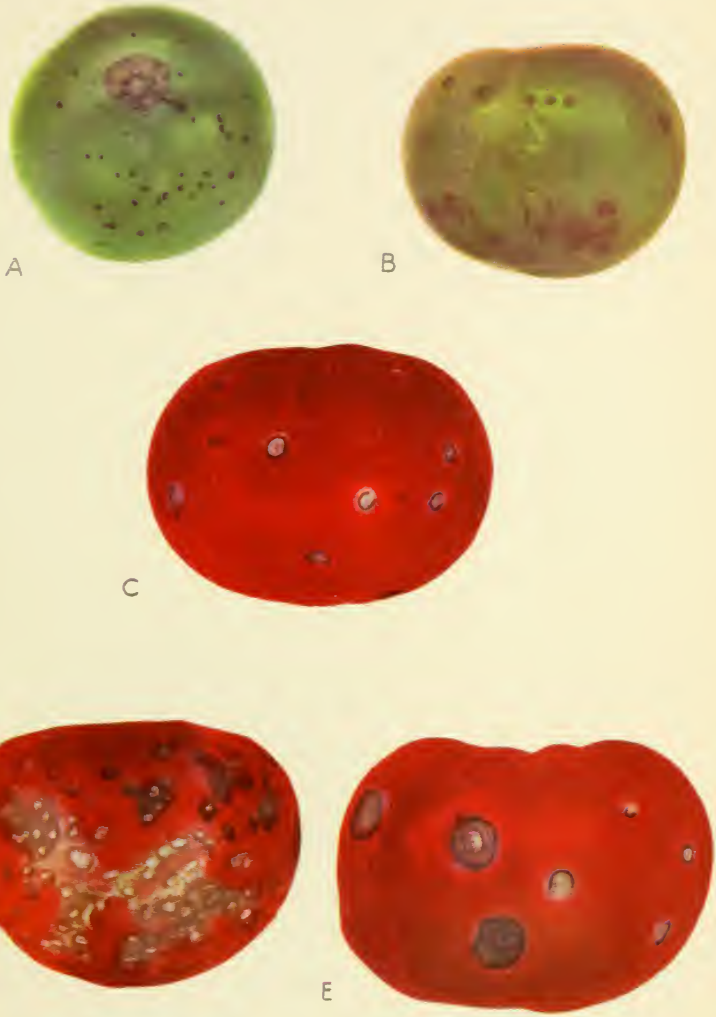
NAILHEAD SPOT

(*Macrosporium tomato* Cke.)

OCCURRENCE, SYMPTOMS, AND EFFECTS

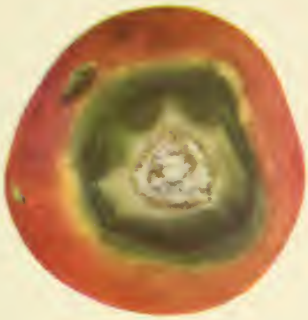
Nailhead spot of tomatoes occasionally is one of the most serious diseases encountered in the shipping of green wrapped tomatoes from Florida and Mexico. Before resistant varieties were introduced commercially, losses often involved from 10 to 50 per cent of the crop. In recent years, however, more and more of the Marglobe variety has been planted, and this highly resistant variety has almost eliminated nailhead spot as a problem in many sections. Experience has shown, nevertheless, that the organism is still present in the fields and that serious trouble may be expected with susceptible varieties grown under moist weather conditions which favor the development of this disease. For related leaf and vine diseases see Alternaria Rot, page 3.

Nailhead spot acquires its common name from the characteristic small, circular, slightly sunken, grayish-brown to brown superficial spots produced on the fruit. (Pl. 6, C, D.) In the early stages

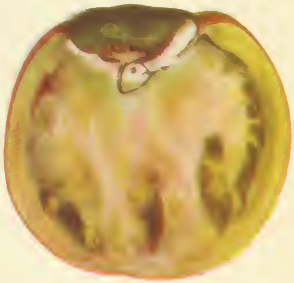


NAILHEAD SPOT OF TOMATO

A and B, Early stages; C, D, and E, medium and late stages

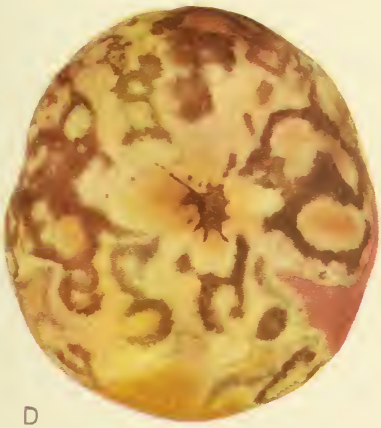


A



B

C



D

E

SULPHUR DIOXIDE INJURY AND STREAK OF TOMATO FRUITS

A and B, Sulphur dioxide injury; C, D, and E, streak

the spots are flat and tan in color, but as they enlarge the margins become more definite and dark brown to black, while the centers change to grayish brown and become definitely sunken. (Pl. 6, A, B, C.) Spots range in size from one-sixteenth to three-eighths of an inch in diameter, the average being less than one-fourth of an inch. In ripe or turning fruit the lesions are sometimes surrounded by a halo of tissue in which the green color is retained.

When not contaminated by other organisms, the typical nailhead spot is a shallow blemish and does not penetrate the wall of the tomato. The blemish stage is particularly characteristic of the disease in Florida, but occasionally in Mexican stock a decay follows the blemish. (Pl. 6, E.) Whether this decay is due to continued growth of the nailhead organism or to a related species following as a secondary agent is not definitely known. (See Alternaria Rot, p. 3.) Nailhead spot in Mexican tomatoes is sometimes also followed by green-mold rot. (See p. 14.)

CAUSAL FACTORS

The fungus *Macrosporium tomato*, which induces this disease, probably lives over from season to season on plant débris and on related crop plants or weeds. The spores of this fungus are readily disseminated by wind, water, insects, and man. Under moderate temperature and moisture conditions the spores may germinate and penetrate into the uninjured tissues of a tomato plant. Typical nailhead spots are the result of field infection of unwounded, immature, green fruits. Field, transit, and market experiments show that most of the infections take place before the fruit reaches a diameter of 2 inches, but that new infections may take place in fruits of any marketable size. Infection is correlated with maturity, and size is not necessarily indicative of maturity. The rate of development of nailhead spot is noticeably more rapid in green tomatoes, and decreases uniformly as the fruit matures.

Under favorable conditions it has been found that as high as 19 per cent of commercially packed tomatoes from Florida may develop new nailhead spots during transit to Chicago. The average diameter of these new spots developed during transit is one-sixteenth of an inch. Nailhead spots of all sizes present at shipping time enlarge to some extent, the rate of enlargement being inversely proportional to the original size of the spots at shipment. For example, spots one-sixteenth of an inch in diameter and smaller usually almost double their size during six days in transit, while those one-eighth to one-fourth of an inch in diameter enlarge very little during the ordinary transit period, unless there is secondary invasion by some other organism.

CONTROL

If resistant varieties are not obtainable, seedlings should be sprayed while in the seed bed with a 3–4–50 Bordeaux mixture. After plants are set in the field, spraying with a 5–5–50 Bordeaux mixture is advisable.

Spotted fruits should be discarded at the time of packing, to avoid danger of secondary contamination and decay during transit. (*59*, *64*, *65*, *67*, *77*, *88*.)

PHOMA ROT

(*Phoma destructiva* Plowr.)

OCCURRENCE, SYMPTOMS, AND EFFECTS

Phoma rot is one of the most important diseases affecting tomatoes during transit and marketing. The disease also affects plants in the field and causes decreased yields and fruit of poor quality. The southern or winter grown tomatoes suffer most seriously. Affected fruit is not only unsightly but is also subject to progressive and complete decay.

The pathogene attacks both the green and the ripe fruits. On green tomatoes the early stage is characterized by small, slightly sunken spots, usually at the edge of the stem scar. (Pl. 1, C.) As these spots enlarge, they develop brown to brownish-black centers, which become dotted with the brownish-black pycnidia. (Pl. 1, D.) On ripe tomatoes the first evidences of the decay are water-soaked concave spots. As the spots enlarge they remain slightly sunken, slightly discolored, and water-soaked. By the time the lesions reach a diameter of one-half inch, most of the sunken area is charry black, leathery, and firm, and is dotted with black pycnidia. (Pl. 1, E.) In a humid atmosphere, white, slimy spore masses may ooze out of the pycnidia. At times the dry crustlike center of the lesions cracks, and the grayish-white mycelium develops in the crevices. This cracking usually is followed by the invasion of secondary soft-rot producing organisms.

Phoma rot penetrates into the pulp of the tomatoes, and the spots may enlarge indefinitely. The underlying tissues are brown or black and remain firm until the spots become very large or are infected with secondary organisms.

The lesions occur more frequently at the stem end of the fruit, where the fungus enters through growth cracks or mechanical injuries. They may, however, occur wherever there are breaks in the skin of the fruits.

In the early stages the spots on the leaves are small discolored areas with a definite but irregular outline. These spots are brown to black in color and often start at the leaf margins and enlarge into irregular blotchlike areas. Badly affected leaves dry out and are shed prematurely, with the result that the leaf surface and consequently the yield is reduced, while danger of sun scald of the fruit is increased. On the petioles and stems of the tomato plants the diseased areas appear as dark streaks or blotches. Black pycnidia develop in these lesions after the tissues die.

CAUSAL FACTORS

The pathogene is the fungus *Phoma destructiva.* It overwinters in the soil in plant débris of the previous season and probably on seed from infected fruits and on weeds. From these sources it attacks the plants and is spread from plant to plant by insects, rain, wind, and man. Tomato fruits apparently are resistant to the attacks of this fungus unless growth cracks, insect injury, or other wounds open the way.

Growth of the fungus is favored by a temperature of approximately 80° F., but it can grow at temperatures as low as 42° and

as high as 90°. Spread and development of the disease take place during rainy weather or when there are heavy dews to supply suitable moisture for spore germination. It is practically certain that all the fruits in affected fields are contaminated with the spores of Phoma, but unless the skin is broken no infection takes place. The incubation period is 4 days for fruit infection, and for leaf infection it is 3 to 5 days under most favorable temperature conditions. Fruit that is wounded at packing time may therefore be free from decay but develop visible decay within 4 days. Phoma spots become quite distinct in 10 days and develop the black pimplelike pycnidia in the center of the spots in about three weeks. At 64° in a humid atmosphere spots on ripe fruit may reach a diameter of 1 to 2 inches in 8 days. Decay develops more rapidly in ripening fruits than in green ones. Wounded tomatoes may be expected to develop Phoma rot during transit and in the ripening rooms, but apparently little or no spreading from one fruit to another takes place after the tomatoes are wrapped.

CONTROL

Crop rotation and the planting of disease-free seed are recommended for control of this disease in the field. To avoid loss during transit, careful handling is necessary to prevent cracking or wounding of the fruits. Tomatoes showing spots should not be packed. (*37*, *41*, *64*, *77*, *88*.)

PUFFINESS

Puffiness is one of the most important physiological diseases of tomatoes grown for the winter market. The definite cause of the disturbances that result in the production of puffy fruits is not known. Nutritional disturbances in which moisture and high-nitrogen fertilizers appear to play the chief rôle are believed to be one cause of this type of trouble. Phosphorus deficiency with the resultant underdevelopment of pulp causes a type of puffiness. Inhibited development of the placentae due to mosaic also causes a somewhat similar kind of puffiness.

Puffy tomatoes are easily detected by their flattened sides, spongy texture, and light weight. When the fruit is cut, large air spaces are found in the cavities normally occupied by the seeds. No decay or discoloration takes place in fruit of this kind, but it is unmarketable on account of poor texture and appearance. (*42*, *88*.)

RHIZOPUS ROT

(*Rhizopus* sp.)

Rhizopus rot is one of the important secondary diseases of tomato fruits when they are turning color or ripening. It is rarely found on green tomatoes, and it does not affect the growing plant. The spores of this fungus are ever present in the air, and since it is almost entirely dependent upon wounds for entry into plant tissues, Rhizopus is likely to occur in tomatoes from any region whenever conditions favoring infection and growth of the fungus prevail. As indicated above, it is practically limited to ripe fruits during transit and in the ripening rooms on the market.

The decay produced by Rhizopus is typically soft and watery, and very often the odor of fermentation is quite noticeable. The lesions produced through wounds on any part of the fruit are large, red, blisterlike areas which penetrate deeply into the pulp of the tomato and cause a total collapse of the tissues within a few hours. If infection takes place through a slight wound, the fungus may entirely destroy the internal tissues and convert the fruit into a "water bag" without showing external signs of mold. This type of decay is also common in peppers. (Pl. 10, A.) The characteristic coarse white mycelium and the white and black sporangia are generally in evidence, however, to establish definitely the cause of the decay. (Pl. 5, D.)

Rhizopus nigricans Ehrenb. ex Fr., which induces most of the Rhizopus rot in vegetables, is considered a high-temperature fungus. It makes very poor growth at temperatures below 44° F., grows best between 77° and 82°, and is checked by temperatures above 90°. (See Potato, Rhizopus Soft Rots, p. 40.)

SCLEROTIUM ROT (SOUTHERN BLIGHT)

(*Sclerotium rolfsii* Sacc.)

Sclerotium rot is relatively unimportant on tomatoes except in Florida. The inciting organism is prevalent in the trucking soils of the Southern States, but is of economic importance only during wet seasons, and then it is often more destructive on other crops than the tomato. (See Potato, Sclerotium Rot, p. 46.)

This disease is indirectly a market factor, because of its attack upon the growing plant, causing wilt and a reduction in the set of fruit. It is also a direct factor because it is characterized by a decay of the fruit in the field, in transit, and on the market. The fungus grows in and on the surface of moist soils and attacks such fruits as come in direct contact with the soil or become spattered with soil containing some of the mycelium. (See Soil Rot, p. 26.) The early indications of Sclerotium rot are yellowish, slightly sunken spots on the lower half of the tomato. Development is rapid and the epidermis is soon ruptured. Over the surface of the shriveled fruit a fine silky weblike or fan-shaped mycelium is often visible, and in the older parts of this mycelium small white tufts appear. These tufts are the beginnings of sclerotia, which when mature appear round and brownish in color like mustard seed.

The geographic distribution of *Sclerotium rolfsii* is apparently controlled by climatic factors, in which temperature plays the important rôle. At a temperature of 68° F. or below, its growth is very slow. Once the fungus is in the soil, about the only recommendation for its control is deep plowing, which buries the sclerotia so deep that they are killed or are unable to attack the succeeding crop. No fruits showing yellowish watery spots should be packed for shipment. (*88.*)

SEPTORIA LEAF SPOT (BLIGHT)

(*Septoria lycopersici* (Speg.) Sacc.)

OCCURRENCE, SYMPTOMS, AND EFFECTS

Leaf spot is widely distributed but is most destructive in Maryland, Virginia, West Virginia, New Jersey, Indiana, Ohio, Utah, and adjoining States. In severe epiphytotics the leaf spotting is so general and disastrous as to cause a blighting of the whole plant and premature dropping of the leaves. Affected plants produce a poor yield and the fruits that are formed are of poor quality and subject to sun scald. Septoria has never been observed to cause decay of tomatoes on the market and is very rarely found spotting fruits in the field.

The older leaves of the plant are the first ones affected with the small water-soaked spots occurring on the lower side. As the spots enlarge they become definite in outline, more or less circular in shape, and the affected tissues become dark and sunken. The color of the center of the spots varies from gray to brown. In the later stages pycnidia appear as black specks in the center of the spots.

A few fruit spots have been observed in Indiana tomatoes, but apparently this phase of the disease is not of serious consequence. The lesions are shallow and irregularly circular in outline and about one-eighth of an inch in diameter. The border of these spots is black and the center grayish white as in the leaf spot. In some of the fruit spots the characteristic black pycnidia are evident.

CAUSAL FACTORS

Septoria lycopersici is a fungus that overwinters on tomato-plant débris of the previous season and on various weed plants, provided these are not covered with soil. Early in the summer the spores are discharged and infect the seedling plants. The spores are scattered by wind, rain, and man. The fungus does not produce spores readily unless the temperature lies between 59° and 80.5° F. At 50° a month is required for spore production. In view of the fact that the fungus does not thrive and cause infection unless humid or wet conditions prevail, the disease usually does not get under way, in the sections where it is more severe, until June 15 to 30. Under favorable temperature conditions the inoculation period is about 5 days, and after 13 days mature pycnidia and spores are developed.

CONTROL

Economical control involves modification of field practices. Since the disease is late in getting started, its effect can be offset to a great extent by setting out early in the spring large, stocky, well-hardened plants about 6 weeks old. They can be produced cheaply in the South for northern use.

Overwintering of the pathogene can be prevented to a large extent by plowing under old tomato vines in the field. In addition, fields and their environs should be kept as free as possible from dead weeds and grasses that can harbor the fungus.

If seed is dipped for 5 minutes in a solution of 1 part of mercuric chloride in 3,000 parts of water and rinsed in water for 10 minutes, and if the seedlings are sprayed two or three times with Bordeaux mixture before being set out, development of the disease in the seed bed can be prevented.

In the field the disease can be controlled by repeated sprayings with 4–4–50 or 4–2–50 Bordeaux mixture. The effectiveness of the spray is improved by the addition of 2 to 3 pounds of resin fish-oil soap to each 50 gallons of solution. (*27*, *39*, *46*, *53*, *54*.)

SOIL ROT

(*Rhizoctonia solani* Kühn (*Corticium vagum* Berk. and Curt.))

OCCURRENCE, SYMPTOMS, AND EFFECTS

Soil rot is found chiefly in tomatoes from Florida, Cuba, Texas, Mississippi, California, and Mexico, but since the inciting agent is practically omnipresent in vegetable-growing regions, it is occasionally found during wet seasons in tomatoes from many localities. Although the common soil fungus, Rhizoctonia, is responsible for this disease, and the original infection takes place in the field, some of the greatest losses for which it is responsible occur during transit and in the ripening rooms. Fruits that are in contact with the soil, or near enough to be spattered with soil, are the sites of the original infections. Wet soil conditions are necessary for the development of soil rot in tomatoes, and when these conditions prevail there is great loss of fruit in the field and in the packing house as well as during transit and marketing.

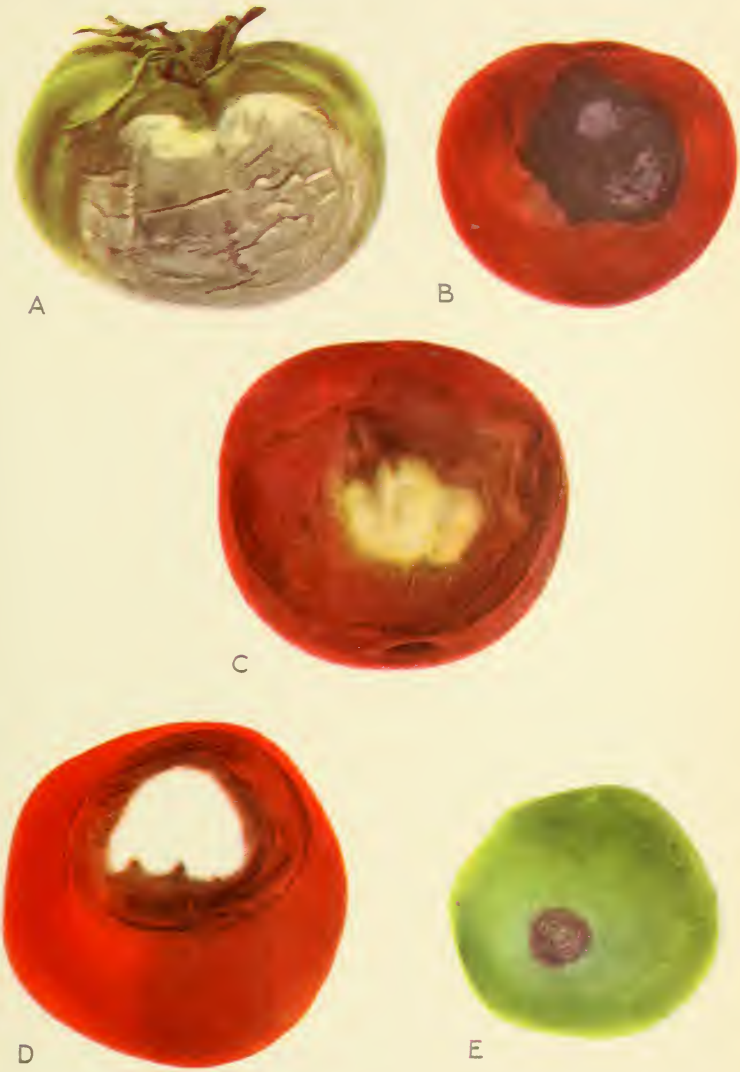
On green tomatoes in the field the first visible symptoms of soil rot are small circular brown spots on the lower half of the fruit. Spots one-fourth of an inch in diameter and larger usually show very definite concentric ring markings made up of alternating zones of light and dark brown tissues. (Pl. 9, E.) As the tomato ripens and the fungus makes more rapid growth these rings become obliterated and are usually not in evidence by the time the fruit reaches the market. Very often as the tomatoes turn pink the tissues immediately surrounding the spot retain part of the green color, thus forming a greenish-brown border around the lesion. On ripe fruits the lesions are moderately firm and reddish brown in color, bordered by reddish-brown water-soaked areas. (Pl. 8.) Although the spots are not sunken, they are often 1 to 2 inches in diameter, and when the epidermis over these larger lesions ruptures, the crack becomes filled with brown mycelium and sclerotia. Cream-colored or brown mycelium is often visible on the surface of the tomatoes when they arrive on the market, and may penetrate the moist wrappings, forming irregular brown sclerotia on them as well as on the fruit. (Pl. 8.) Frequently the paper wrap becomes firmly attached to the tomato at the place where such mycelial mats occur.

CAUSAL FACTORS

The fungus *Rhizoctonia solani*, which induces this disease, is present to some extent in the soil in all vegetable-growing regions. The amount of damage caused in any one season is entirely dependent upon weather conditions. If the surface soil is wet and the plants

BASKET OF TOMATOES SHOWING SOIL ROT (RHIZOCTONIA) IN VARIOUS STAGES

Note the brownish mycelium and sclerotia on the paper wraps



TOMATO FRUIT DISEASES AND INJURIES

A, Sun scald; B, Alternaria rot; C, sun scald followed by bacterial soft rot; D, Fusarium rot; E, soil rot (Rhizoctonia) in early stage on green tomato

are large enough to cover the ground and maintain a high degree of humidity underneath the vines, this fungus may attack any or all of the tomatoes that come in contact with the soil or that become spattered with soil during heavy rains. The spore-producing stage (Corticium) of this fungus apparently plays no part in fruit infection, consequently only those fruits are attacked that come in contact with bits of the mycelium. For this reason staked tomatoes are much less likely to become affected with soil rot than those not staked.

Field, transit, and storage experiments have shown that the fungus can enter tomato fruits through an apparently sound epidermis. Tomatoes showing no signs of decay at shipping point have been found to develop as high as 10 per cent soil rot during five days in transit. Both green and ripe fruits are affected. In about half of the cases the lesions develop where there is no evident break in the epidermis, while in the remainder the organism enters through wounds and stem and blossom scars. New lesions that develop during transit usually reach a diameter of approximately one-half inch within five days. The small spots ranging from one-sixteenth to one-fourth of an inch in diameter, which constitute the majority of those overlooked in commercial grading and packing, attain an average diameter of eleven-sixteenths of an inch in five days in transit. Owing to the increased rate of decay as the spots enlarge and the fruit ripens, the above-mentioned lesions often reach a diameter of from 1 to 1¼ inches within seven days. These lesions are so conspicuous and penetrate into the fruit to such an extent that all affected tomatoes are a total loss.

CONTROL

The only way to control soil rot is to stake the tomato vines so that the fruits will not hang near or touch the soil. When this disease is extremely prevalent in the field it is sometimes advisable to stop packing tomatoes for a few days so the affected fruits may decay or develop spots large enough to be recognized and sorted out before packing. As high as 60 per cent soil rot has been found on the market in cars that were loaded from wet fields showing this disease. No tomatoes showing brown spots should be packed, for they are likely not only to decay but to infect the neighboring tomatoes as well. (*40*, *60*, *64*, *88*.)

STREAK

Streak has been known as a greenhouse trouble for many years. In recent years it has been recognized as a serious field disease of tomatoes also, although the causal factors still are imperfectly understood. Early work indicated that it was a bacterial disease, but more recent investigations have demonstrated that it is closely allied with the mosaic disease. (See Mosaic, p. 19.) It has been shown that certain viruses alone, and some virus mixtures (tobacco mosaic virus plus healthy-potato virus) will produce streak when introduced into tomato plants.

All parts of a tomato plant, including the fruits, may show symptoms of streak. The plants are dwarfed, and in advanced stages

of the disease the leaves roll and wither enough to cause death of the whole plant.

The young topmost leaflets usually show irregular yellow mottling first. The yellowish areas later turn brown and die, and the edges of the leaves roll down and inward. The leaf petioles and stems of affected plants are brittle and show long brown streaks, while on the fruits light-brown sunken irregular areas or slightly elevated brown greasy-appearing areas are characteristic. (Pl. 7, C.) Occasionally the surface of badly affected fruits cracks. The disease may also be characterized by more or less extensive brown discolorations of the surface of the fruits, which may result in a great diversity of pattern, such as circular spots, blotches, loops, and streaks. (Pl. 7, D, E.) These areas are somewhat sunken, and on green fruit the brown color may be absent, in which case the disease manifests itself as variations in the intensity of the green color. The affected tissues are firm and hard and do not decay unless infected by some fungus or bacterium. Immature fruits do not ripen. The brownish surface discoloration of the ripening fruits sometimes penetrates the inner tissues and entirely destroys the marketability of the fruits. Affected tissues are susceptible to invasion by secondary decay-producing organisms during transit and marketing.

No effective control measures are known. (*5*, *6*, *81*, *85*, *86*.)

SULPHUR DIOXIDE INJURY

Injury to tomato fruits caused by exposure to sulphur dioxide gas has been observed on the markets in stock shipped from California and Florida. So far only a few cars have been found showing this type of trouble, but the seriousness of the injury warrants mention in this publication. The injury results from burning sulphur in cars of tomatoes, or using sulphur dioxide gas, as is practiced with certain commodities in California, to reduce the amount of decay during transit and marketing. No experimental data are available, however, to show that sulphur dioxide is of value in reducing decay in cars of tomatoes.

The tomatoes affected show a very pronounced sinking and drying out of the tissues at the stem scar. (Pl. 7, A, B.) The gas enters the fruits through the stem scar or through wounds elsewhere on the surface. The cells immediately surrounding the openings are killed and lose their water rapidly by evaporation, causing collapse of the affected region. In some instances the stem scar is sunken one-half inch and the tissues immediately around the scar are bleached to a sickly greenish-tan color, while the remainder of the tomato remains normal except where mechanical injury is evident. Wherever the cuticle and epidermis of a fruit show a wound, the surrounding tissues are sunken and bleached greenish tan like those around the stem end. The sunken stem scars dry rapidly and crack, thus opening the way for various decay-producing organisms, such as Alternaria and Rhizopus. (*57*.)

SUN SCALD

Sun scald occurs on many tender vegetable tissues when they are exposed suddenly to intense, hot sunlight without previous opportunity for accommodation to such conditions. Consequently, it fre-

quently occurs in tissues that develop in shaded sites and then are suddenly exposed to intense light. This occurs as a secondary consequence in diseases in which the foliage is suddenly destroyed, as in watermelon, muskmelon, and cucumber anthracnose, or in tomato wilt and late blight. It may also follow topping of onions or digging of potato tubers. Leafy tissues also are sometimes affected by sun scald.

In fleshy fruits, such as tomatoes, the young, immature, green-colored tissues generally are affected. Thus, ripe tomatoes or peppers do not sun scald. Sun scald is evidenced by death and discoloration of rather extensive areas on the exposed side of the organ. In most cases the lesion is irregular in outline and at first resembles a water-soaked blister, but soon becomes slightly though sharply sunken and distinctly bleached in color. (Pl. 9, A.) Bleaching is particularly noticeable in peppers, tomatoes, cucumbers, and melons.

Since some time must elapse between occurrence of the injury and development of the symptoms, it happens that fruit (especially tomatoes) packed when apparently sound may develop lesions in transit.

The lesions are important on the market, not only because they disfigure the fruit, but even more so because they open the way for rot-producing fungi. In onions bacterial rots usually follow; in tomatoes bacteria, Fusarium, or Alternaria usually enter; in melons Alternaria, green mold (Cladosporium), and black mold (*Aspergillus* sp.) are the secondary invaders.

In so far as sun scald follows other diseases, control of these diseases involves sun-scald control. Fruits, bulbs, and tubers should be protected againt intense sunlight and high temperature at harvest time. Scalded fruits should not be shipped, because they are unsightly and, by opening the way for decay, jeopardize healthy tissues.

WATERY ROT

(*Oospora lactis parasitica* Pritchard and Porte)

Watery rot of tomato fruits occurs quite generally in tomato shipments from Southern States and is sometimes destructive in the field.

The disease has many characteristics in common with the soft rots caused by *Bacillus carotovorus* and *B. aroideae.* Like these, it is characterized by an extremely watery appearance, by the absence of any discoloration, and by oozing of juice. Unlike these, however, in humid air the lesions become covered with a white, velvety to granular growth of fungus. In dry air there is no fungus growth. The decay, which generally starts at the stem scar, in growth cracks, or through other wounds, has a tendency to develop in the form of sectors extending to the blossom end of the fruits. It has a sour, fermenting, unpleasant odor.

The pathogene affects both ripe and green fruits, usually the former. The fungus grows through a wide range of temperature, from 36° to about 100° F., growing best at about 86°, and infects tomato fruits readily between 50° and 87°.

The decay does not progress as rapidly as the bacterial rots, especially in ripe fruits, although it may destroy an entire tomato in two to five days.

There is some promise that antiseptic washes may be perfected which will tend to lower the losses due to this and possibly other soft rots. Washing tomato fruits for 30 minutes in an aqueous solution of chloride of lime 1:40 or formaldehyde (37 per cent) 1:240 gives a marked reduction of decay in experimental lots. (*50*, *55*.)

YELLOWS

(Curly-top virus)

OCCURRENCE, SYMPTOMS, AND EFFECTS

The disease now termed yellows was previously known under the name western yellow blight. It has recently been shown, however, that the infective principle (virus) is the same as, or at least very similar to, that which induces curly top in sugar beets, and that this virus is carried by the beet leaf hopper, *Eutettix tenellus* Baker. Since the virus diseases transmitted by leaf hoppers are generally grouped under the term yellows, the tomato disease is now referred to as tomato yellows.

Yellows was first thought to be a western disease of rather limited geographic distribution, but it has since been found rather widely scattered. It causes most damage in the following States: Washington, Oregon, California, Idaho, Utah, Arizona, and New Mexico. The annual loss varies from a slight amount in some years up to half of the crop or more during a year when the disease is severe. Affected plants bear few fruits that reach a marketable size, and since there are no lesions produced on the fruit, the malady is of only indirect market significance.

Yellows becomes evident about the time the first blossoms appear and increases in prevalence and severity as the season progresses. The first indications of the disease are an upward and inward rolling of the leaflets and a more erect position of the leaves, which finally droop, but do not wilt. The plant loses its normal green color and becomes grayish to faintly purplish, and finally becomes yellow throughout. Affected plants are stunted, the fruits are small and immature and usually are of poor quality. The erect position of the leaves becomes more pronounced, the rolling and stiffness increase, and the yellow green of the plant changes to a dirty sulphur yellow. On the roots the disease is manifested by brownish discoloration at the tips of the small feeding roots and by brown decaying areas on the larger roots.

Although the presence or absence of the beet leaf hopper, which carries the virus from plant to plant, determines to a great extent the amount of yellows developed, the environment also plays an important part. Most severe attacks have been noted during periods of intense sunlight and high temperature. Plants exposed to high temperature and wind develop the disease much more readily than those in protected situations.

CONTROL

The breeding of resistant varieties promises to be the best field for development of practical control of this disease. No dusts or sprays have proved effective in killing or repelling the beet leaf hopper. Temporary muslin tents which protect the plants from

insects and create conditions less favorable for the development of the disease have proved a benefit, but this type of control measure is impractical in most instances. (*43*, *44*, *71*, *72*, *73*.)

PEPPERS

The pepper of the vegetable market is the fruit of the pepper plant (*Capsicum annuum* L.), a member of the nightshade family. In some varieties the fruits are usually picked green (bell peppers), while others are allowed to ripen and are marketed as redpeppers.

There are several field diseases that attack pepper plants and indirectly affect the quantity and quality of the fruits. These are Cercospora leaf spot (*Cercospora capsici* Heald and Wolf), Fusarium wilt (*Fusarium* sp.; see Potato, p. 25), cotton root rot (*Phymatotrichum omnivorum* (Shear) Duggar), Sclerotium rot (*Sclerotium rolfsii* Sacc.; p. 24), and southern bacterial wilt (*Bacterium solanacearum* (E. F. Smith) E. F. Smith; see Potato, p. 14). The most common insect injuries are due to aphids (*Illinoia solanifolii* Ashm.), flea beetles (*Epitrix parvula* Fab. and *E. cucumeris* Harris), garden flea hopper (*Halticus citri* Ashm.), hornworm (*Protoparce sexta* Johan.), and root knot (*Caconema radicicola* (Greef) Cobb).

A second group of diseases attacks both the growing plant and the fruits. These are Alternaria rot (*Alternaria* sp.), anthracnose (*Colletotrichum nigrum* Ell. and Halsted), bacterial spot (*Bacterium vesicatorium* Doidge; pl. 10, B; p. 7), gray-mold rot (*Botrytis* sp.), mosaic (p. 19), ripe rot (*Vermicularia capsici* Syd.), and Sclerotinia rot (*Sclerotinia sclerotiorum* (Lib.) Massee).

A third class of diseases affects only the fruits. In this class fall bacterial soft rot (*Bacillus* sp.; p. 7), blossom-end rot, buckeye rot (*Phytophthora terrestria* Sherb.; p. 10), Phoma rot (*Phoma destructiva* Plowr.; p. 22), Phytophthora rot (*Phytophthora capsici* Leonian), Pythium rot (*Pythium debaryanum* Hesse), Rhizopus rot (*Rhizopus* sp.; pl. 10, A; p. 23), Sclerotium fruit rot (*Sclerotium bataticola* Taub.), and sun scald (p. 28). (*93*, *94*, *95*, *100*.)

ALTERNARIA ROT

(*Alternaria* sp.)

Alternaria rot is often observed on pepper fruits in the field and frequently causes serious losses during transit and marketing. In most instances infection takes place at the blossom end, probably following blossom-end rot. The disease is characterized by dark-green watery lesions which are covered with grayish-brown to black velvety mycelium.

The identity of the pathogene has not been established; it may be *Alternaria solani* (p. 3).

ANTHRACNOSE

(*Colletotrichum nigrum* Ell. and Halsted)

OCCURRENCE, SYMPTOMS, AND EFFECTS

Anthracnose of peppers is a disease that frequently causes serious losses in the field. In the market it is a factor not only because it

blemishes and decays fruit but even more because it opens the way for secondary organisms, especially Alternaria species.

The disease is evidenced by tan, slate-colored, or charry to black sunken lesions on the fruit. (Pl. 10, C, D, E.) The margins of the lesions are dark green, water-soaked, and wrinkled. (Pl. 10, C.) Under moist conditions there occur salmon-colored dots or spore heaps which may run together and form a slimy mass in the center of the lesions. (Pl. 10, E.) These dots are the acervuli of the fungus and furnish a positive diagnostic character for the disease. Very frequently under transit and market conditions the lesions do not bear acervuli but became covered with a black velvety growth of Alternaria. (Pl. 10, C.) (See Alternaria Rot, p. 3.)

CAUSAL FACTORS

The pathogene, *Colletotrichum nigrum*, affects both young and mature fruits and forms great numbers of spores in the lesions. The spores are spread from plant to plant by insects, rain, and wind. The details of the life history of this fungus have not been worked out, but it is thought that the mycelium may remain viable over winter in old fruits left in the field and may thus serve as the source of inoculum for the new crop.

CONTROL

Spraying with Bordeaux mixture is recommended for control of the disease in the field. Cold storage at 32° F. with relative humidity of 90 per cent will control the development of anthracnose on the fruit without injury to the peppers. (*92*, *95*.)

BLOSSOM-END ROT

OCCURRENCE, SYMPTOMS, AND EFFECTS

Blossom-end rot of peppers occurs frequently in the field and is also found on fruits in the markets. The disease is a market factor because it disfigures the fruit, and more especially because it opens the way for bacterial and fungus invaders, of which *Alternaria* sp. is an important one. The disease is similar to blossom-end rot of tomato fruits, of melons, and of cucumbers.

The first symptoms are slight depressions at or near the blossom end of half-grown fruits. The depressed area is water-soaked and is either slightly lighter in color than the surrounding tissues or a darker green. Although the spots enlarge, they do not involve the entire end of the fruit as in tomatoes. As a general rule the lesions become invaded by secondary organisms with subsequent production of rots involving the entire end of the fruits. The formation of depressed areas is associated with death and collapse of those inner cells which surround the ends of the small veinlets. Usually blossom-end rot occurs only on half-grown, green fruits.

The disease seems to be associated with a temporary wilting of young pepper plants at a stage when the fruits are about half grown. In this stage of development of the plants the root system is characteristically poorly developed and shallow and there are relatively few fruits, although those present are large and growing rapidly.

PEPPER FRUIT DISEASES

A, Rhizopus rot; B, bacterial spot; C, D, and E, anthracnose in various stages; C shows some secondary Alternaria

With the plant at this stage, a sudden change in the water relation, due either to a deficiency of water in the soil or to a sudden onset of increased water loss from the leaves, brings on wilting and attendant collapse of the more tender cells of the fruits. Because of their poorly developed root systems, plants in a very wet soil have a tendency to develop the disease when sudden excessive water loss occurs.

CONTROL

Control is not an easy matter. It involves maintenance of an adequate water supply and prevention of sudden increase in water loss while the fruits are half grown. (*96.*)

CERCOSPORA LEAF SPOT

(*Cercospora capsici* Heald and Wolf)

Although Cercospora leaf spot occurs wherever peppers are grown commercially, it is seldom of much economic importance unless the season is excessively wet.

Small, water-soaked spots, which later turn papery and white with slightly brownish margins, are produced on the leaves. Severe infection causes yellowing and dropping of the foliage. The pedicels are sometimes attacked, and frequently the pathogene works down through them, causing a stem-end decay of the pod.

Spraying with Bordeaux mixture is suggested as control for this disease. (*95.*)

FREEZING INJURY

As in the case of other vegetable crops produced for marketing in the North during the winter and early spring months, the pepper is sometimes subjected to freezing temperatures in the field and during transit and storage. To insure against freezing injury all peppers should be protected against temperatures approaching 30.1° F., since this has been determined experimentally as the average freezing point for green peppers.

Peppers affected by freezing have a water-soaked, flabby texture, and the epidermis has a tendency to blister or rub off easily. In severe cases the stem becomes soft and dark and the core and seeds may be darkened and slightly brown. As the water evaporates from the affected tissues the walls of the fruit collapse and the whole pepper becomes worthless. (*98.*)

GRAY-MOLD ROT

(*Botrytis* sp.)

A disease frequently found affecting peppers on the market, and one especially likely to be found in stock held in cold storage or elsewhere, is gray-mold rot. The inciting fungus, Botrytis, grows well at low temperatures and can produce decay in most vegetables at 32° F. Consequently it may be found causing decay under a wide variety of conditions. On peppers the decay induced is quite characteristic, its most definitely diagnostic feature being the pres-

ence of the grayish-brown mycelium and granular spores over the surface of the lesions or within the fruit. In most instances the decay starts at either the stem end or the blossom end of the fruit, but lesions may be found anywhere on the pod. The young lesions are greenish and water-soaked, changing to gray or grayish brown with age. As the spots enlarge they may become more or less irregular in outline, but the line of demarcation between the diseased and healthy tissues is usually quite distinct. Although this semiwatery decay develops rapidly at moderate temperatures and may cause total collapse of the fruit within a few days, no obnoxious odor is produced. In peppers showing advanced stages of decay, black, irregular, crustlike sclerotia may be found in the seed cavity and on the seeds.

No control has been developed. (*98*, *102*, *104*.)

PHYTOPHTHORA ROT (STEM BLIGHT)

(*Phytophthora capsici* Leonian)

OCCURRENCE, SYMPTOMS, AND EFFECTS

Chili peppers in New Mexico sometimes show considerable damage from Phytophthora rot. Apparently the disease is not of economic importance elsewhere and has not been observed on the market.

Small green water-soaked spots are the first indications of this disease on the fruit pods. In mild cases the infected areas enlarge little, but in severe attacks they elongate and may involve one-fourth or more of the pod. Since the lesions develop lengthwise much more than laterally, they become long and narrow, sometimes extending the full length of the fruit. Affected tissue soon bleaches out to a dull straw color and becomes parchmentlike and sunken. In severe cases the seeds become infected, turn brown, shrivel, and die, or the infection may be confined to the seed coat.

The organism passes from the fruits to the young branches and often extends to the larger branches, which may be completely girdled and killed. When the main stem is reached the fungus usually stops growth, and thus one half of a plant may be killed while the other half remains healthy. If, however, the primary infection takes place on the main stem, the entire plant is killed.

CAUSAL FACTORS

The pathogene, *Phytophthora capsici*, is carried over from year to year in infected seeds, and once established in the soil, it is very difficult to eradicate. Since the low-hanging pods are the ones usually infected, it is thought that spattering raindrops carry the zoospores upward from the soil to the fruits. Under favorable conditions, visible lesions may appear within 24 hours after inoculation. The disease is favored by warm, rainy weather.

CONTROL

Careful seed selection is recommended for control of this disease. No spraying experiments have been tried. (*101*.)

PYTHIUM ROT

(*Pythium debaryanum* Hesse)

Pythium rot has been found affecting peppers in North Carolina. The inciting organism, however, is known to be present in the soils of most vegetable-growing regions, consequently this type of disease should not be considered localized. During wet weather this fungus is able to attack a wide variety of vegetables, inducing a rapidly progressing watery decay frequently referred to as leak. (See Potato, Leak, p. 33.)

Only peppers that touch the soil or hang low enough to become spattered with soil during rains are affected. The small water-soaked spots near the blossom end of the fruit, which form the first evidences of the disease, enlarge rapidly, the affected tissues becoming grayish green, watery, soft, and slightly sunken. The whole fruit becomes involved within four or five days. In advanced stages the affected tissues become slightly brown and an abundant white cottony mycelium is found within the pod and growing out on the surface when the epidermis has been ruptured.

No methods of controlling this disease in the field have been worked out. During wet seasons special care should be taken not to pack for shipment fruits on which water-soaked spots are evident. This type of decay develops very rapidly under transit conditions and is likely to spread to healthy fruits. (*99.*)

RIPE ROT

(*Vermicularia capsici* Syd.)

A new fruit rot of peppers that is particularly damaging to the canning crop of central Georgia has been reported since 1928. In certain limited areas the growers of pimentos estimate their loss to be 50 per cent of the crop. During wet weather the rot develops very rapidly, and the fruits are completely decayed within a few days. Seemingly sound fruits harvested from infested fields have been known to deteriorate overnight to such an extent that over half of them had to be discarded at the cannery.

The first symptoms appear on ripening pods as whitish to light-pink circular spots, approximately one-eighth to one-fourth of an inch in diameter. These in later stages become water-soaked and soft, with dirty-brown to black centers and reddish-brown borders. The centers of the large spots are sometimes covered with masses of pink spores as in anthracnose. (See Anthracnose.)

The organisms inciting this type of decay are not well differentiated. *Colletotrichum nigrum* induces decay in both green and ripe pimentos, whereas the decay found in Georgia is apparently limited to ripe fruit. The fungus Vermicularia has been found to remain somewhat dormant for a month or more within the epidermal tissue of green pimentos without producing external symptoms of disease. Decay develops rapidly in the fruits as soon as they begin to ripen, and the fungus is soon found invading the seed cavity. The mycelium enters the seed, in many instances causing dark discoloration.

Seed from diseased fruit should not be planted. Since the fungus is within as well as on the surface of the seeds, no disinfectants can

be relied upon. It is not known whether the fungus can live over winter on diseased plants or in the soil. (*97.*)

SCLEROTIUM FRUIT ROT

(*Sclerotium bataticola* Taub.)

The organism inducing Sclerotium fruit rot in peppers is much better known as the inciting agent of charcoal rot in sweetpotatoes. Inoculation experiments have shown, however, that the fungus may induce decay in the following additional hosts also: Tomato, eggplant, turnip, cucumber, and apple. It has caused some fruit rot on peppers in New Jersey, but is not likely to become important. No peppers showing this disease have been observed on the markets.

Peppers usually show very little external evidence of the disease except a shriveling and drying of the epidermal tissues. The interiors of the pods are discolored, however, and a great number of small black specks (the sclerotia of the fungus) are visible within the tissues and on the seeds. Experimental evidence indicates that the fungus will enter through wounds and become established in four days and that complete decay of the fruit results in about two weeks.

No control methods are known. (*103.*)

EGGPLANTS

The eggplant of the market is the large, fleshy fruit of a strong perennial herb (*Solanum melongena* L.) which is grown as an annual in the vegetable garden. The dark-fruited or purple varieties are most popular in the United States, while the white-fruited ones are more in demand in Europe. To command a good price on the market the fruits must be large, firm, well colored, and free from decay and blemishes.

The eggplant is subject to many diseases that attack other members of the nightshade family. Anthracnose (*Colletotrichum* sp.), cottony leak (*Pythium aphanidermatum* (Edson) Fitz.), fruit rot (*Phomopsis vexans* (Sacc. and Syd.) Harter), Phytophthora rot (*Phytophthora terrestria* Sherb.), and Rhizoctonia fruit and stem rot (*Corticium vagum* Berk. and Curt.; p. 26) are the only parasitic diseases that are direct factors in the marketability of the fruits. Freezing, however, often causes losses in transit. Gray-mold rot (*Botrytis* sp.; p. 14) and Rhizopus rot (*Rhizopus* sp.; p. 23) occur occasionally on the market.

Field diseases are of indirect importance in the market because they lead to the production of small, poorly shaped, and poorly colored fruits. The important ones are aphid injury (*Illinoia solanifolii* Ashm.), blister beetle injury (*Epicauta vittata* Fab.), Cercospora leaf spot (*Cercospora melongenae* Welles), early blight (*Alternaria solani* (Ell. and Martin) Jones and Grout; see Potato, p. 4), flea-beetle injury (*Epitrix parvula* Fab. and *E. cucumeris* Harris), hornworm injury (*Protoparce sexta* Johan.), Nectria stem rot (*Nectria ipomoeae* Halsted), root knot (*Caconema radicicola* (Greef) Cobb; see Potato, p. 41), Sclerotium blight (*Sclerotium rolfsii* Sacc.; see Potato, p. 46), Septoria leaf blight (*Septoria lycopersici* (Speg.) Sacc.), southern bacterial wilt (*Bacterium solanacearum* (E. F

Smith) E. F. Smith; see Potato, p. 14), and Verticillium wilt (*Verticillium albo-atrum* Reinke and Berth.; see Potato, p. 50). (*107*, *108*, *111*, *113*, *114*, *115*.)

ANTHRACNOSE

(*Colletotrichum* sp.)

Usually of little importance, anthracnose occasionally causes some damage to eggplant during wet seasons. Small yellowish and brown spots on the leaves and large brownish sunken spots on the fruits are characteristic of the disease. In humid weather salmon-pink masses of spores ooze out of the acervuli in the center of the larger spots. Spotted fruits are of little market value and are very susceptible to decay in transit by secondary rot-producing organisms.

Sometimes the stem and roots are attacked, causing a wilt of the plant.

No control measures are known.

COTTONY LEAK

(*Pythium aphanidermatum* (Edson) Fitz.)

Except for the more rapid development and the production of a greater abundance of white, cottony mycelium under humid conditions, cottony leak is typical of vegetable diseases induced by other Pythium species. Eggplants from Tennessee and Florida have been observed to show this trouble during wet seasons. Only fruits that come in contact with the soil or become spattered with soil are affected; consequently the decay originates at the blossom end in practically all instances.

First symptoms of the disease are bleaching of the purple color, a tan discoloration, and slight wrinkling of the epidermis. The affected tissue underneath is watery, and light brown in color. Slight pressure causes a brownish liquid to flow freely from the diseased tissues. At ordinary temperatures affected fruits become completely decayed within three or four days and a great abundance of white cottony mycelium covers the surface. Apparently, wounds are not necessary for infection by this species of Pythium, although most diseases of this type are known to be almost entirely dependent upon wounds for opening the way to the inciting organism.

No control methods for preventing the development of this disease in the field have been developed. Since the decay progresses so rapidly, it is obvious that no fruits showing brownish discolorations of any kind should be packed for shipment. All fruits affected at shipping time are sure to decay, and the fungus may spread to healthy fruits in the hampers. (*105*.)

FRUIT ROT (PHOMOPSIS BLIGHT)

(*Phomopsis vexans* (Sacc. and Syd.) Harter)

OCCURRENCE, SYMPTOMS, AND EFFECTS

Fruit rot is the most common and destructive decay of eggplants found on the market. It affects eggplants from all regions, but causes greatest damage in the South. Occurrence and severity of

the disease in the Northern States seem to be somewhat correlated with high temperatures. In fields severely infested the yield is often reduced 50 per cent, and sometimes 90 to 100 per cent of the crop is affected.

On the fruit the young lesions are more or less circular, tan to light brown in color, and slightly depressed. The spots become darker brown with age and enlarge sometimes to a diameter of 2 to 3 inches; often two or more coalesce, covering the whole fruit. (Pl. 11, A.) The decay is soft and spongy and penetrates throughout the tissues of the fruit, causing a light-brown discoloration. (Pl. 11, B.) Pycnidia, larger than those found on the leaf stems and midrib, are formed just under the epidermis in the more advanced lesions and appear as small brownish pimples. When they break through the surface their black tops or beaks are easily visible to the naked eye. In badly affected or mummified fruits these pycnidia often literally cover the surface. If such fruits are held in a humid atmosphere for some time the spores ooze from the ripe pycnidia and germinate, giving rise to white wefts of mycelium about each pycnidium, thus giving a white appearance to the surface of the fruit mummy.

CAUSAL FACTORS

There are no available data relative to the overwintering of the pathogene, *Phomopsis vexans*, nor are there data available relative to the method of penetration, incubation period, or the relation of environmental factors such as temperature and moisture.

CONTROL

Bordeaux mixture has been reported to give good results when young plants are sprayed and kept covered with the spray material. Rotation of crops, use of disease-free seed, and soil sterilization are beneficial in controlling the disease. It is claimed by some that the disease is carried over in the seed and that treatment with mercuric chloride (1 to 300) is advisable.

Development of resistant varieties has been undertaken but has not progressed far enough to warrant recommendations. (*106*, *109*.)

PHYTOPHTHORA ROT (BLIGHT)

(*Phytophthora terrestria* Sherb.)

Phytophthora rot or blight is induced by the same pathogene that is responsible for a rot of pepper fruits and for the rot of tomato fruits known as buckeye rot.

On the eggplant the disease is marked by dark-brown spots with conspicuous light-colored borders, the dark-brown decay extending well into the flesh. The vascular tissues show up as darkly discolored strands running from the decayed area into the stem end. Invasion of the stem end probably is responsible for the fact that fruits drop when more than one-half of the fruit becomes decayed.

Another Phytophthora rot of eggplant has been described as due to the same fungus that causes tomato late blight (see p. 17). In the eggplant this fungus attacks the fruit petioles and calyxes and causes a decay of growing fruits. (*110*, *112*.)

A

B

PHOMOPSIS FRUIT ROT OF EGGPLANT

A, External appearance; B, longitudinal section

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